Monitoring Aquatic Benthic Ecosystems of the Bruce Peninsula

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MONITORING AQUATIC BENTHIC ECOSYSTEMS OF THE BRUCE PENINSULA

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Introduction

Long-term ecological monitoring documents changes within an ecosystem over an extended period of time. The establishment of permanent monitoring sites provides early warning signs of potential ecological problems and offers information on which to base management strategies. The goal of ecosystem management is to adopt practices that will lead to sustainability. In terms of water management, the goal is to achieve a state in which water use has a minimal affect on the integrity our aquatic ecosystems. By evaluating aquatic conditions two questions can be answered: (1) how does water quality vary over time and space, and (2) are management efforts resulting in progress toward sustainability (i.e., are aquatic systems minimally impacted?) (Jones et al., 2003).

Biomonitoring is a term used to describe the assessment of biological condition: the biological condition of streams in the case of this study. The Ontario Benthos Biomonitoring Network (OBBN) is a provincially standardized program that was co-founded by the Ontario Ministry of the Environment and Environment Canada (both the National Water Research Institute and Ecological Monitoring and Assessment Network). The OBBN provides a standardized protocol for biomonitoring rivers, lakes, and wetlands using benthic invertebrates, also known as benthos (bottom dwelling insects, crustaceans, worms and other animals large enough to see with the naked eye) (Jones et al., 2003). Benthos are good indicators of aquatic ecosystem health for many reasons including their widespread distribution, ease of collection and identification, relatively long life cycles, limited mobility (sedentary habitats, unlike fish), and varying tolerances to physical and chemical changes. They can be readily archived and preserved for future reference. Benthos can be used as early-warning signs and as surrogate indicators because they respond to stressors after relatively short exposure and are not seen as an economic or recreational resource themselves (unlike fish and ducks, for example) (Jones et al., 2003). The OBBN also uses a reference condition approach to biomonitoring, which is discussed below.

Biomonitoring is important because it can evaluate biological responses to a range of natural and human factors directly. Also, biomonitoring is complementary to widely applied physical habitat and chemical monitoring approaches. Biological assessment measures the direct response of stream communities to a range of environmental variables in order to distinguish impaired from unimpaired sites. Chemical assessment measures concentrations of indicator parameters to identify possible cause of impairment to stream communities. Biological conditions will identify impaired sites to direct watershed management programs and chemical results can be used as a management tool by comparing them to guidelines. Therefore, successful monitoring programs should include both chemical and biological approaches.

The purpose of the Ontario Benthos Biomonitoring Network is to evaluate aquatic ecosystem condition using benthic macro-invertebrates, to measure the effectiveness of the program, and to provide a biological performance measure related to management of aquatic ecosystems. The Bruce Peninsula Biosphere Association, a non-profit, community-based organization, addresses local environmental concerns by taking an approach that allows for informed decision-making in support of a sustainable community while maintaining a balance between local development and ecological conservation. A major aspect of the Association's objectives is capacity building, providing support for research, monitoring, education and information exchange related to local issues of conservation and development. By participating in this long-term biomonitoring program with the OBBN the Biosphere Association meets it's main objectives while establishing baseline data on several streams in the Municipality of the Northern Bruce Peninsula. The data collected this year and in future monitoring years will be entered into a provincial database and, therefore, have an influence at both a provincial and a local community level.

The reference condition approach (RCA) is an experimental model for aquatic bioassessments used by the OBBN to establish "normal" standards for various habitats. Natural variability among unimpacted sites introduces uncertainty into the process of distinguishing impaired from unimpaired sites. This natural variability makes it very difficult to define "normal" without establishing standards for the various habitats first. The biological condition of minimally impacted reference sites is used to establish the normal range of conditions to be expected at test sites. Reference sites do not have to represent pristine conditions, but areas in which impacts are low and disturbances minimal. The conditions at reference sites should represent the best range of conditions that can be achieved by similar streams within a particular ecological region. In practice, most reference sites will have some anthropogenic impacts; however the selection of reference sites is made from those with the least anthropogenic influences. The RCA has six steps (Jones et al., 2003):

1. Minimally impacted reference sites with a range of physiographic characteristics are sampled.
2. Biological condition is summarized and reference sites are grouped according to similarity of their biological communities.
3. The physiographic or habitat attributes distinguishing the reference groups are noted.
4. The biological community of the test site is sampled and habitat is characterized.
5. The test site is matched with the physiographically most similar reference site group.
6. Statistical tests are applied to determine if the test site community falls within the normal range of biological condition established by the reference group.

When the biological condition at a test site falls outside the normal range defined by reference sites we must assess whether the difference is greater than expected to occur by chance, and whether the difference is biologically meaningful. Further investigation is required to determine if the observed differences were caused by human activities (Jones et al., 2003).

Four reference sites were established on three different streams in the Municipality of the Northern Bruce Peninsula according to protocols provided by the Ontario Benthos Biomonitoring Network. The streams included in this initial study were Spring Creek, Willow Creek, and Crane River. Each site includes three replicates with four transects at each. Catchment physiography, site characteristics, and substrate characteristics were recorded for each site so that the data can be used to compare to similar streams in the local area and province-wide. The reference sites are an attempt to determine the "normal" range of biological conditions so that test sites can be established in the future. Benthic biomonitoring was completed at each replicate using the Traveling Kick and Sweep-Transect Method. Numbers recorded for 27 different taxonomic groups at each replicate, and the catchment area data for each site, will be entered into a provincial database and will be available as a comparison against future monitoring studies.

Methods

The following concepts are important to understand with respect to stream sampling and have been taken directly from the OBBN protocol manual (Jones et al., 2003):

1. A “Sampling Reach” is defined as 1 meander wavelength (see Figure 1). The reach begins and ends in a “cross-over”. A cross-over is defined as a location where the thalweg (main concentration of flow, normally the deepest part of the channel cross section) is in the center of the channel during the bank full discharge. Cross-overs occur where the thalweg crosses from one side to the other side of the longitudinal mid line of the channel; by definition, they occur at intervals of ½ the meander wavelength. Cross-overs are usually associated with riffles because current speed at a cross-over point is relatively homogenous across the channel cross section at bank full discharge (when the stream has its greatest erosive energy). Typically, at cross-overs, the banks on either side of the channel are about the same height.

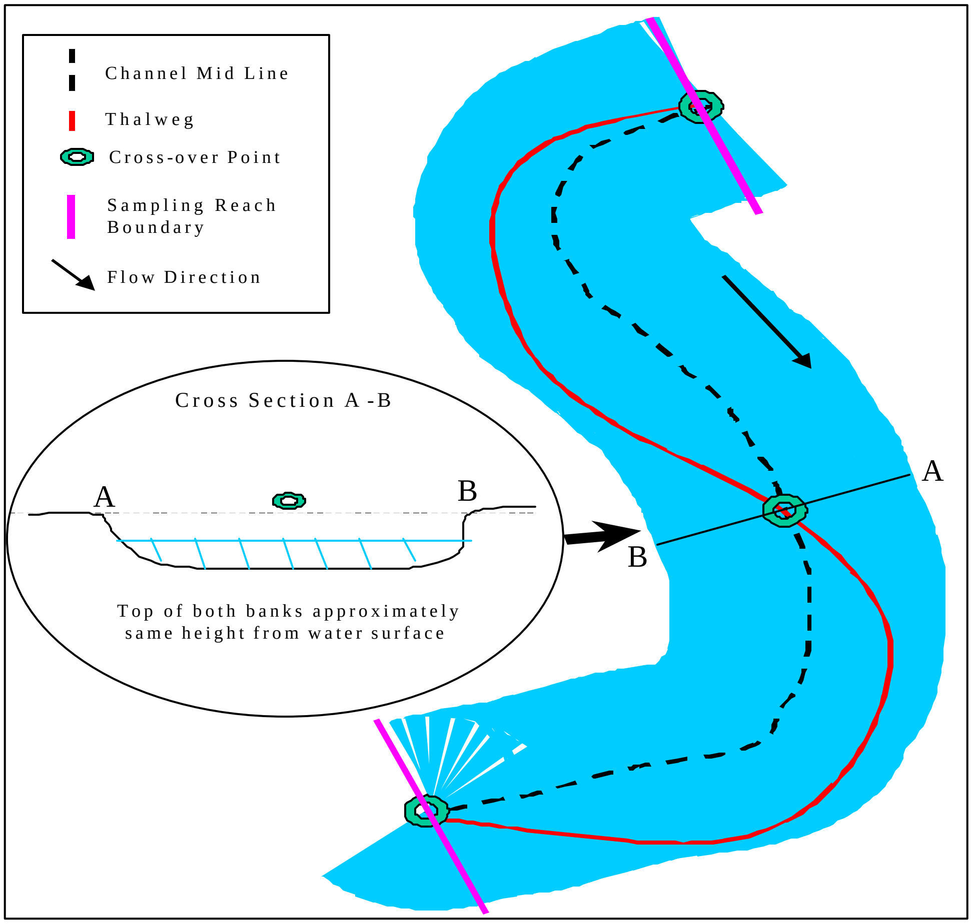


Figure 1: A typical stream meander wavelength showing key morphological attributes used to define a sampling reach (taken from OBBN manual, 2003).

2. Replication is at the sampling reach level. Four transects make up one replicate and there are three replicates at a site therefore; one site consists of twelve transects. Samples may be pooled within the sampling reach (four transects), to generate a composite replicate that represents relative benthos densities throughout the sampling reach, the second and third replicates that are typically collected in distinct (often adjacent) reaches.

The benthos collection protocol for streams follows:

1. Apply appropriate safety measures.
2. Fill out a field data sheet (1 per site). A blank field data sheet is shown in Appendix 1 and the details for filling it out follow the benthos collection methods. Benthos collection should be completed before filling out the site characterization information on the field sheet so that you minimize disturbance of the stream bed.
3. Identify a sampling reach that consists of one full meander wavelength (beginning and ending at a cross-over). In the case of altered or atypical channels, where natural meander sequences are not evident or are difficult to discern, the length of the meander wavelength can be estimated as 14-20 times the bank full width, since in most moderate gradient streams, cross-overs are repeated at a frequency of 7-10x the bank full width. The position of the cross-over can be inferred as a location where banks on both sides of the channel have similar height and water depth and is fairly uniform across the channel cross section.
4. Select appropriate collection method. For wadeable or partially wadeable streams, use a Traveling Kick-Transect method (Figure 2). (Note: All of the streams studied in this report were monitored using this method). Refer to the OBBN manual for collection methods for non-wadeable streams (Jones et al., 2003).

Traveling Kick and Sweep, Transect Method (Refer to Figure 2):

5. Establish a minimum of four transects in the sampling reach to equally sample pool and riffle habitats and characterize relative benthos throughout the reach.
6. Begin at the downstream transect. Start at the waters edge of either the left or right bank. Place a 500 micron mesh D-net downstream of you with the flat side of the net on the stream bottom. Start your timer. Walk along the transect to the opposite bank, vigorously kicking the substrate to disturb it to a depth of ~5 cm. Large boulders, woody material and other features that are difficult to sample effectively by kicking should be brushed by hand. Sweep the net back and forth and keep it downstream of and close to the area being disturbed so that dislodged invertebrates will be carried onto the net. A good sweeping motion is particularly

important in areas of slow current to ensure animals are collected in the net.

7. Stop timer once the entire bank to bank transect has been sampled and transfer net contents to a bucket.
8. Move to the next upstream transect and repeat steps 6 and 7. Repeat these steps until all transects have been sampled, pooling samples at the end of each transect and tracking the elapsed sampling time. If non-wadeable portions of the channel cross section are encountered as you progress along any transect, sample as much of the transect is safe, then continue to the next transect.
9. Be sure to record the number of transects used, total distance traveled (the sum of the wetted widths at each cross section), total time spent collecting invertebrates (actual kicking and sweeping), bank full and wetted widths at each transect, and the distance between transects (as well as all other information on the field sheet).
10. Repeat steps 3-10 until 3 replicates are collected.

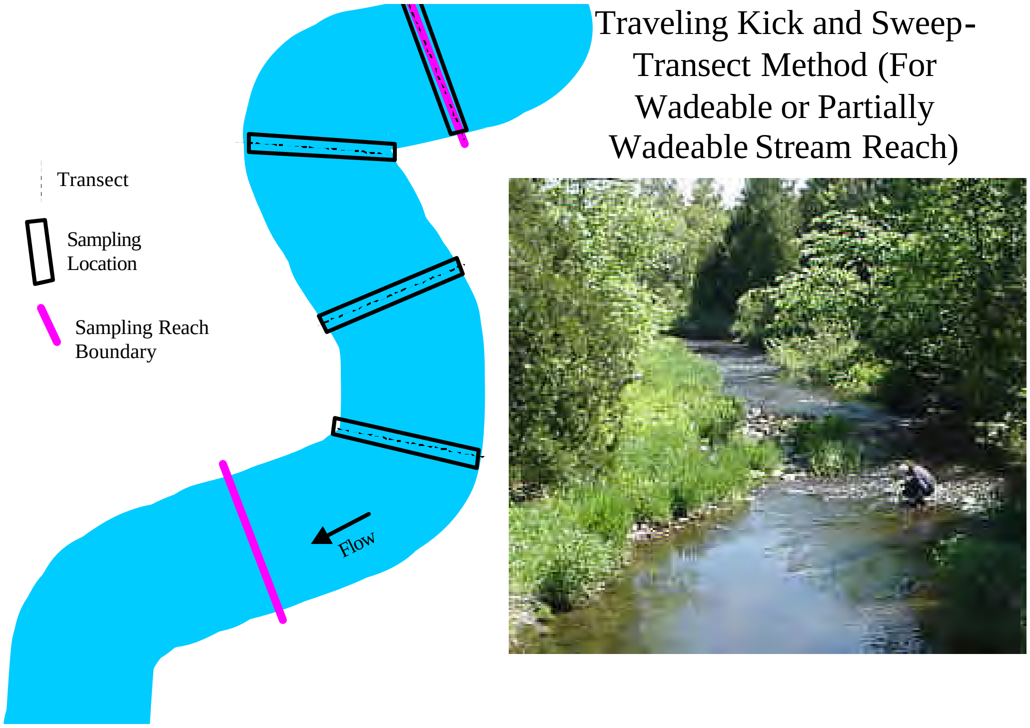


Figure 2: Traveling Kick and Sweep-Transect Method for wadeable or partially wadeable streams (taken from the OBBN manual).

Site characteristics (filling out the field data sheet):

1. Record the elevation and take a GPS reading at transect 1 of each replicate.
2. Record the station #, stream name, and date
3. Mark each transect with flagging tape on either side of the bank. The sites that were established this year should already be marked but they may need to be remarked if the flagging tape was removed.
4. Take photographs of each site and/or draw sketches of the section of stream being studied.
5. Record Arial Coverage Estimates (%) by looking at the percentage of macrophytes, woody debris, and detritus in each replicate. All three numbers should add up to 100.
6. Riparian vegetation is recorded by simply circling the different types present at each site and noting the dominant type.
7. Indicate the different types of aquatic vegetation at each site by placing a check in the box beside each type that is present. Be sure to note the dominant type.
8. Record the water temperature and pH at replicate 1, transect 1. This should be done before benthos collection is completed.
9. Make a note of the weather conditions and the air temperature,
10. Determine conductivity and amount of dissolved oxygen in the stream at replicate 1, transect 1. This should be done before benthos collection is completed. This was not completed this year, however, it is useful information if the proper equipment is available.
11. Substrate characteristics are recorded by entering the dominant and second dominant substrate class for each replicate.
12. Record river characterization, subsampling method, proportion of sample processed, and picking method for each site. Measure the transects by recording max depth, wetted width, hydraulic head, and transect spacing. Complete any additional notes and general comments and fill out any sections that may be missing information.

Sample Processing

Once samples have been collected, sample picking, invertebrate identification and enumeration, and sample preservation should be carried out. Below is a brief summary of the methods involved. For more detailed methods refer to corresponding sections in the OBBN protocol manual (Jones et al., 2003).

Sample picking was carried out on live organisms and was completed on site shortly after benthos collection. Sample picking can also be done in the lab with properly preserved samples. However, live animals are easier to spot and their different movements also help to identify them. The contents of the net from each of the four transects at a replicate is placed together in a bucket. A sub-sample is then taken using either the teaspoon method or Marchant Box method to obtain a

~100 organism count. The sub-sample should be placed in a white sorting tray so that all invertebrates can be spotted and removed. Once an animal is removed it should be identified and recorded on the tally sheet. A blank taxa tally sheet can be found in Appendix 2. Continue taking sub-samples until ~100 animal are counted, making sure to sort and count the last sample to its entirety, even if 100 animals have already been removed. Record the proportion of the total sample processed to obtain the ~100 count, along with the time spent sampling. Three replicates of at least 100 invertebrates are therefore obtained for each site on each sampling occasion.

Results

The locations of the four benthic monitoring sites that were established in the summer of 2003 are displayed in Figure 1. A detailed map for each of the sites displays the location of each replicate, as shown in Figures 4 through 7. Figures 8 through 10 show the watershed boundaries and stream order. A site includes three replicates with four transects at each replicate. Table 1 provides catchment parameters that were obtained by geographical information systems (GIS) and by site-specific habitat variables measured during benthic invertebrate collection (Jones, personal comm.). Catchment parameters can be used to compare streams at a local level and province-wide. Completed field sheets for each site have been placed in Appendix 3. The field sheets can be used to locate the sites and measure the distance to the transects at each replicate so that the same area is being sampled over time.

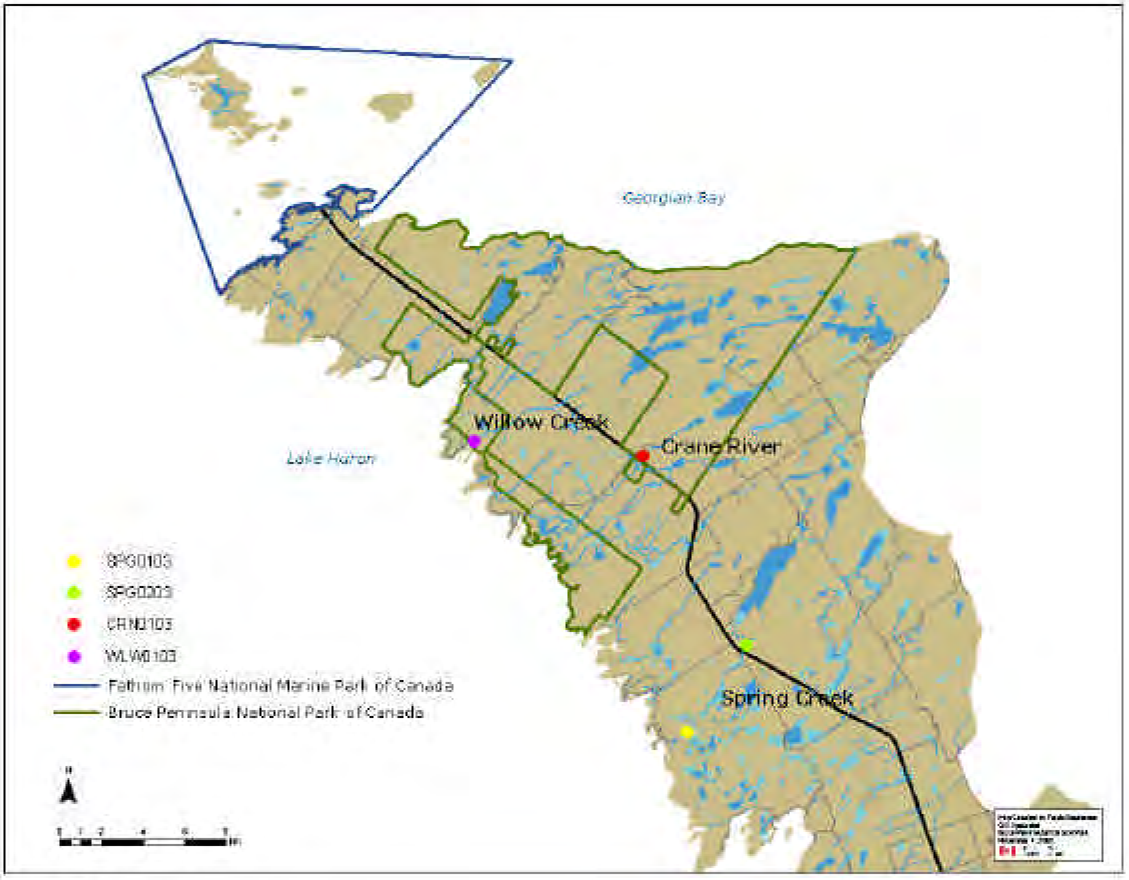


Figure 3: Location of each of the benthic monitoring sites on the Bruce Peninsula, Ontario.

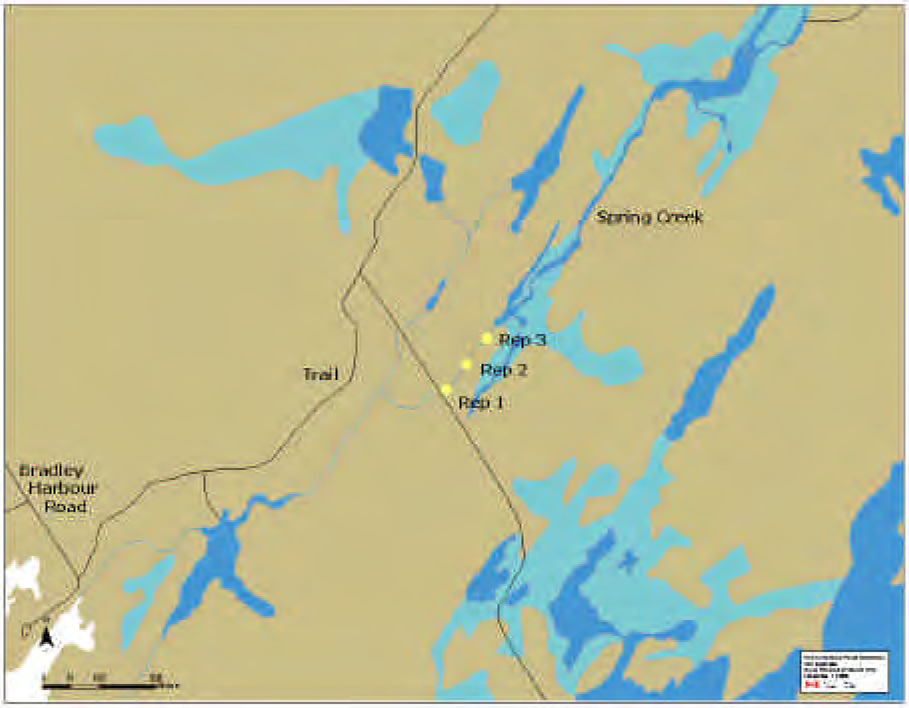


Figure 4: Location of each Replicate at Spring Creek Site 1.

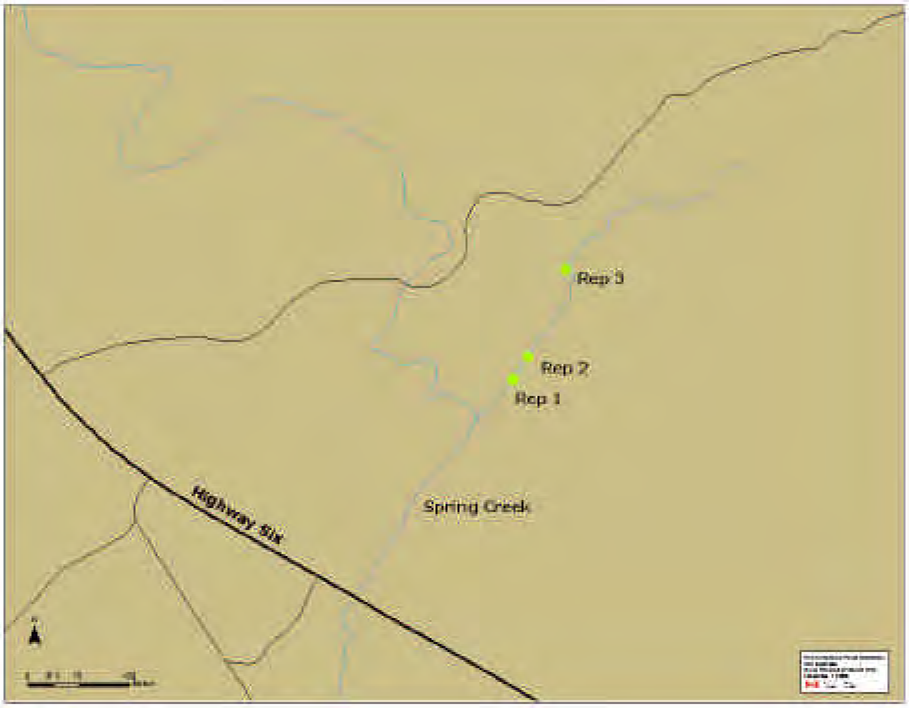


Figure 5: Location of each Replicate at Spring Creek Site 2.

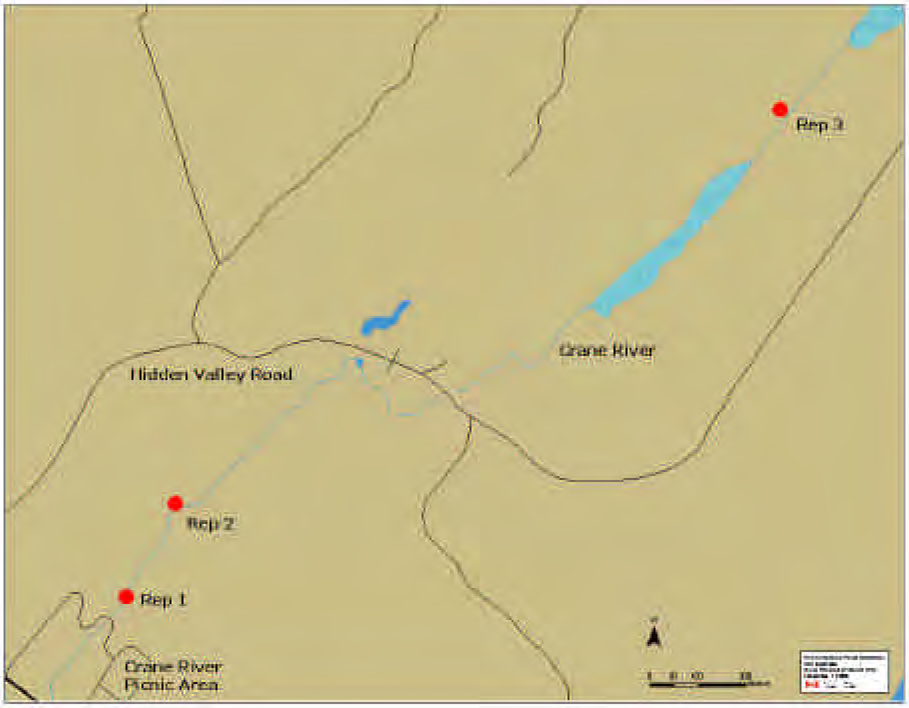


Figure 6: Location of each Replicate at Crane River Site 1.

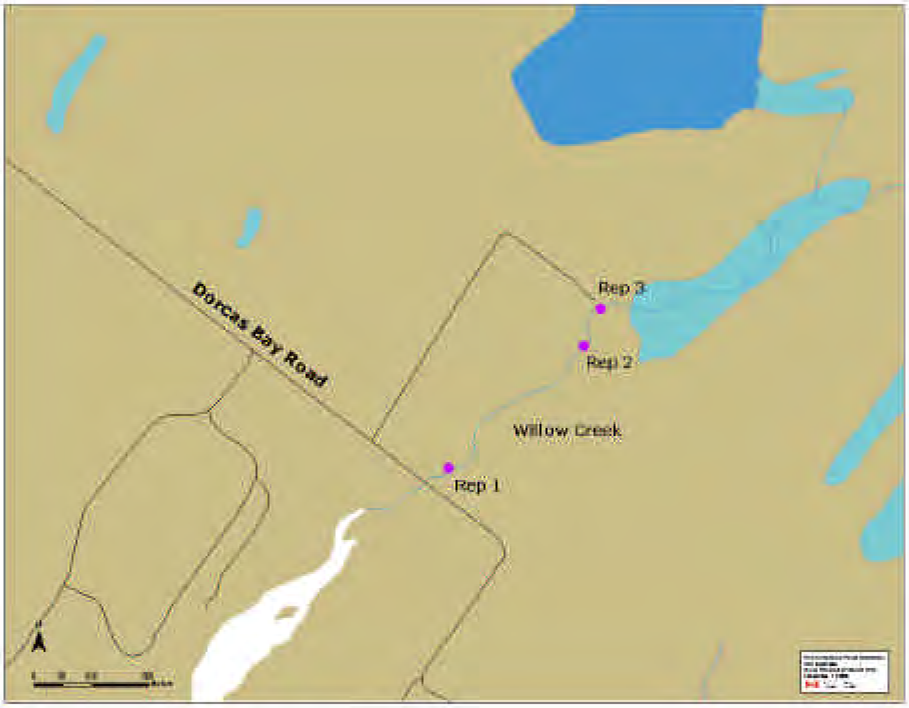


Figure 7: Location of each Replicate at Willow Creek Site 1.

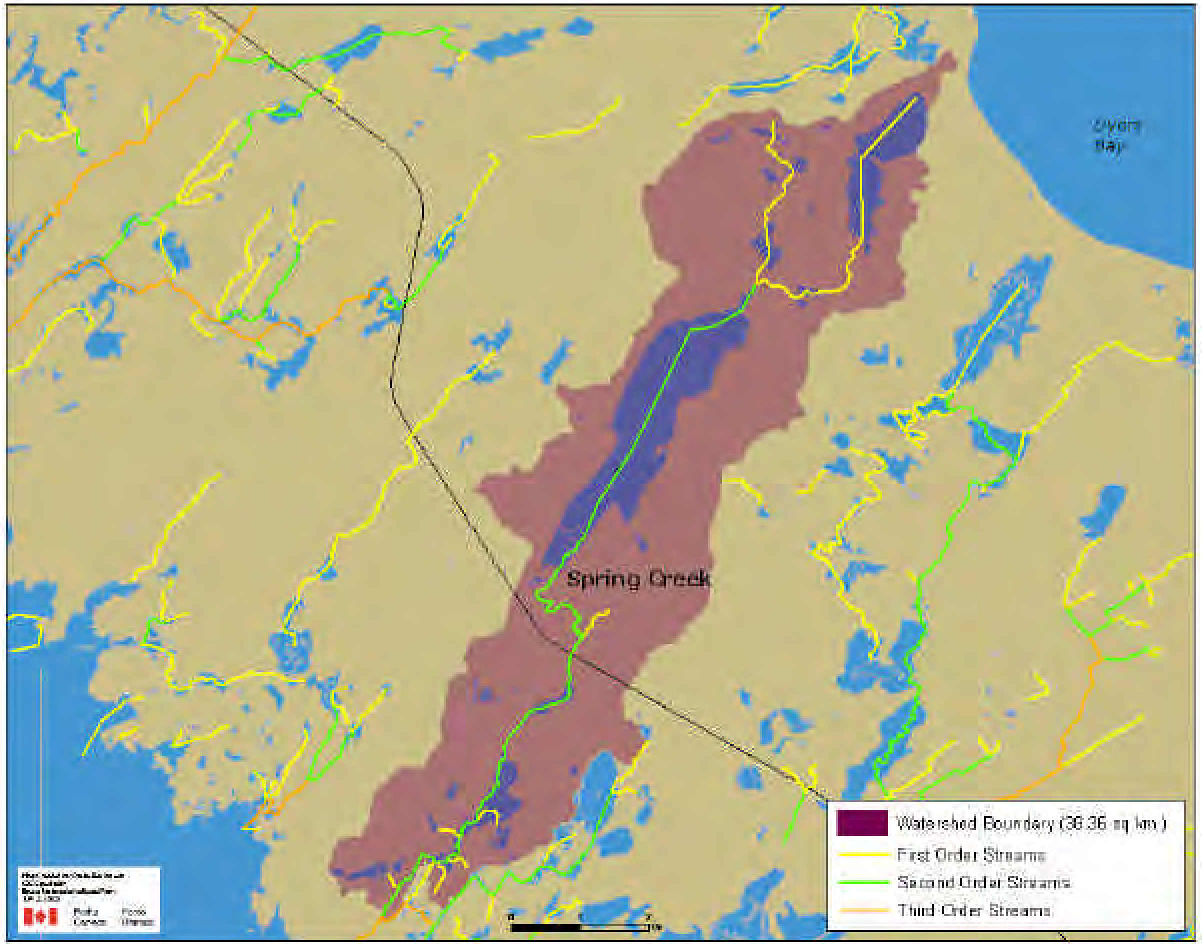


Figure 8: Location of Spring Creek Watershed showing drainage pattern and order of streams.

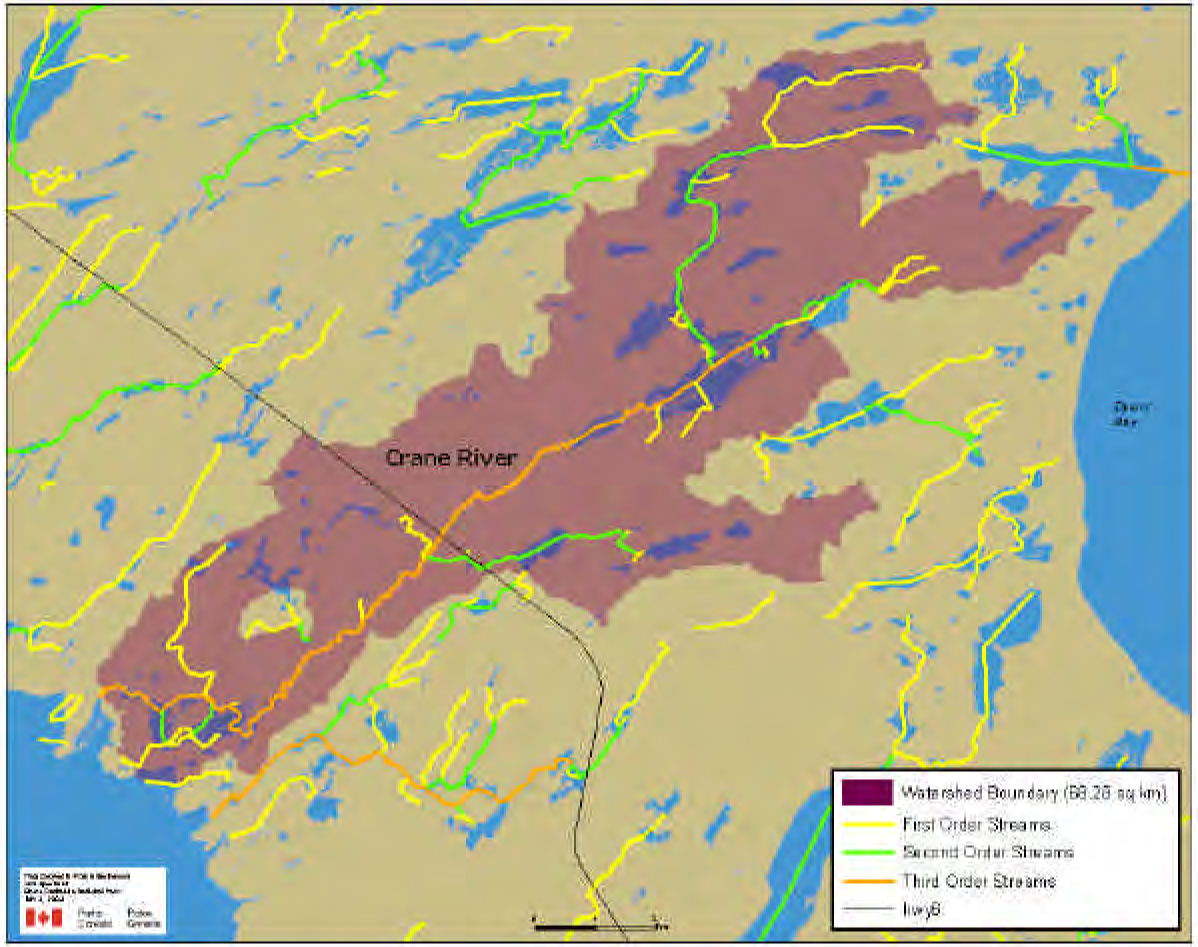


Figure 9: Location of Crane River Watershed showing drainage pattern and order of streams.

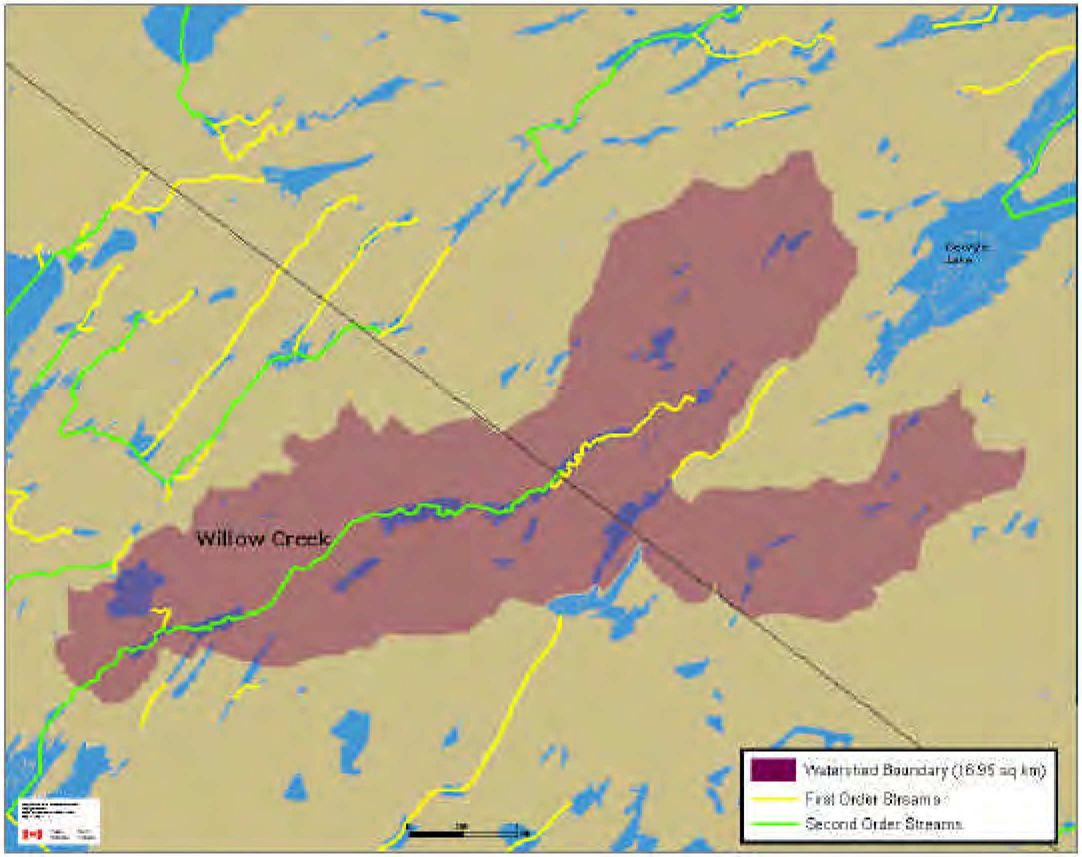


Figure10: Location of Willow Creek Watershed showing drainage pattern and order of streams.

Table 1: Catchment parameters obtained by GIS and site-specific habitat variables measured during benthic invertebrate collection

Parameter	Spring Creek (Site 1)	Spring Creek (Site 2)	Crane River	Willow Creek
Station Name	SPG0103	SPG0203	CRN0103	WLW0103
UTM coordinates	4986606N 0465188E	4990783N 0468008E	4999795N 0463077E	5000510N 0454926E
Drainage (Water Shed) Area (DA)*	1.70 km2	50.53 km2	56.49 km2	19.52 km2
Perimeter (P)	6.92 km	64.88 km	57.60 km	33.72 km
Stream Order	2nd Order stream	2nd Order stream	3rd Order stream	2nd Order stream
% Water and Wetland Cover (ACLS)	12.23%	0.00%	9.84%	2.10%
Length of Main Channel (LNTH)	23.209 km	1.933 km	16.054 km	10.364 km
Slope of Main Channel (SLP)	1.763 m/km	11.602 m/km	1.954 m/km	3.962 m/km
Mean Elevation (ME)	205.666 m	208.722 m	214.159 m	206.257 m
Base Flow Index (BFI)	0.601	0.591	0.618	0.635
River Type	coldwater	coldwater	coldwater	coldwater
Bankfull Width	7.0 m	7.53 m	5.4 m	9.95 m
Mean Wetted Width	7.12 m	6.68 m	6.54 m	7.9 m
Mean Max. Depth	0.226 m	0.245 m	0.394 m	0.284 m
Mean Hydraulic Head	9.25 mm	11.5 mm	10.6 mm	13 mm
Flow Rate	48 cm/s	55 cm/s	55 cm/s	38 cm/s
Dominant Vegetation Type**	Dense Coniferous and Mixed Forest Mainly Deciduous	Dense Coniferous and Mixed Forest Mainly Coniferous	Dense Coniferous and Mixed Forest Mainly Deciduous	Dense Coniferous Forest
Dominant Substrate Types	Bedrock and Cobble	Cobble and Sand	Gravel, Cobble and Boulder	Gravel and Cobble
Dominant Types of Aquatic Vegetation	Attached algae	Emergent Macrophytes	Emergent Macrophytes	Submergent Macrophytes

***** See Appendix 4 for a description of each of the parameters. Taken from the OBBN manual and GIS information received from Chris Jones.

****** See Appendix 4 for a list of % cover of all forest types at each site

Table 2: Raw Taxa Abundance for each Replicate at each of the four sites

	Willow Cr			Spring Cr. (01)			Spring Cr. (02)			Crane R.		
Taxonomic Group	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3	Rep 1	Rep 2	Rep 3
Coelenterata (Hydras)	0	0	0	0	0	0	0	0	0	0	0	0
Turbellaria (Flatworms)	0	0	0	0	0	0	0	0	0	0	0	0
Nematoda (Roundworms)	1	3	3	8	1	0	7	10	6	8	8	0
Oligochaeta (Aquatic Earthworms)	0	1	0	0	0	1	0	0	0	5	0	0
Hirudinea (Leeches)	0	0	0	0	0	0	0	0	0	0	0	0
Isopoda (Sow Bugs)	16	6	8	4	3	18	0	1	1	0	0	0
Pelecypoda (Clams)	0	0	0	0	0	0	0	1	0	0	12	40
Amphipoda (Scuds)	115	36	41	21	12	25	24	135	164	0	7	3
Decapoda (Crayfish)	8	7	7	7	8	5	1	2	6	4	2	5
Trombidiformes-Hydracarina (Mites)	2	0	1	4	0	0	0	0	0	16	0	11
Ephemeroptera (Mayflies)		11	17	11	22	16	3	3	0	29	1	23
Anisoptera (Dragonflies)	21	10	13	8	31	4	2	3	0	8	15	9
Zygoptera (Damselflies)	2	0	1	17	4	0	10	1	1	8	4	2
Plecoptera (Stoneflies)	11	1	10	0	0	0	3	2	2	0	1	1
Hemiptera (True Bugs)	2	5	3	0	0	0	0	0	0	10	9	1
Megaloptera (Fishflies, Alderflies)	4	3	5	8	11	4	3	4	2	0	9	5
Trichoptera (Caddisflies)	35	23	78	54	110	38	21	25	19	7	58	25
Lepidoptera (Aquatic Moths)	0	0	0	0	0	0	0	0	0	0	0	0
Coleoptera (Beetles)	0	0	1	2	12	7	0	0	0	2	1	2
Gastropoda (Snails, limpets)	0	0	0	0	0	0	0	1	0	2	1	4
Chironomidae (Midges)	0	0	16	6	4	3	0	0	0	2	0	5
Tabanidae (Horse and Deer Flies)	0	0	0	0	0	0	0	0	0	0	0	0
Culicidae (Mosquitos)	0	0	0	0	0	0	0	0	0	0	0	0
Ceratopogonidae (No-see-ums)	2	2	4	9	18	9	12	5	3	2	7	1
Tipulidae (Crane Flies)	0	0	0	0	0	0	0	0	0	0	1	0
Simuliidae (Black Flies)	3	2	2	10	0	0	37	17	30	21	9	7
Misc. Diptera (Misc. True Flies)	0	0	0	0	0	0	0	0	0	0	0	0
Total Count	222	110	210	169	236	130	123	210	234	124	145	144

Dominant taxa numbers were taken from the raw data and the mean percentage of each dominant taxonomic group was determined for each site, as shown in Table 3 and Figure 11. Because some within site variation was expected, the 3 replicate samples at each reference site were averaged to produce a mean abundance for each taxonomic group. Diptera includes midges, horse and deer flies, mosquitoes, no-see-ums, black flies, and crane flies. Since all of these Families belong to the same Order they were combined under the heading Diptera.

Table 3: Mean percentage of dominant taxonomic groups at each site.

Taxa Group	Spring 1	Spring 2	Crane	Willow
Scuds	10.8	57	2.4	34.5
Crayfish	3.8	1.7	2.7	3.9
Mayflies	9.1	1	12.9	7.6
Dragonflies	8	0.9	7.8	7.9
Damselflies	3.9	2.1	3.4	0.5
Alderflies	4.3	1.6	3.4	2.2
Caddisflies	37.7	11.5	21.8	24.4
Diptera	11	18.4	13.2	5.6

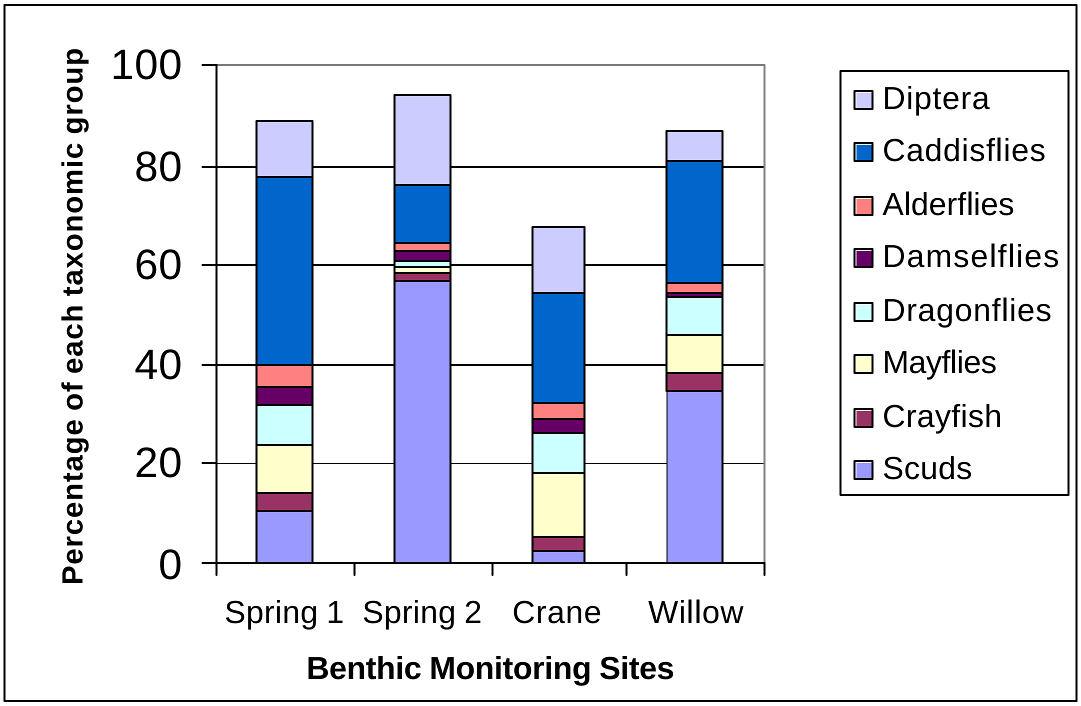


Figure 11: Mean percentage of each dominant taxonomic group at each of the benthic monitoring sites in the Upper Bruce Peninsula Ecosystem, Ontario.

Discussion

Four reference sites were established on three different streams in the Municipality of the Northern Bruce Peninsula according to protocols provided by the Ontario Benthos Biomonitoring Network. Baseline data collected during the initiation of this monitoring program will be useful at both a local community and provincial level. Biomonitoring is essential because it offers methods to determine ecosystem health and the effectiveness of environmental management programs. Benthic invertebrates have many characteristics, such as their sedentary lifestyle, which make them ideal organisms for the purpose of assessing a stream's environmental condition.

It is important to recognize that biological health standards are generally absent for aquatic ecosystems on the Bruce Peninsula. The reference condition approach was used to establish "normal" standards for various habitats in this region. Reference sites were established based on minimal impacts by human use and will be used in the future as a control for impaired site comparison. Once more reference sites are added to the monitoring program and the reference condition is determined, test sites will be included where impairment is suspected. Differences between the reference group and test-site organisms will indicate the degree of impairment of the site. The four reference sites that were studied this summer were quite similar, in terms of catchment physiography and the benthic invertebrates present, and represent a range of conditions that can be used as standards to assess the health of aquatic ecosystems.

Finding just the right location to establish a stream site proved to be quite a challenge. The lack of rainfall caused many of the streams to dry up, preventing many areas from being studied. The presence of beaver dams at several locations along the streams also made it difficult to establish reference sites because upstream from many of the dams are large open marshes. Beaver dams alter the water level of a stream causing poor conditions for reference sites. There were several dams throughout the upper reaches of Spring Creek; therefore, additional reference sites could not be established upstream from Site 2 in the Bruce County Forest. Willow Creek and Crane River were also dammed in several places; preventing the establishment of other reference sites. Lack of accessibility was another factor that added to the challenge of finding ideal reference sites. Many of the streams lack easy access and require very long, strenuous hikes; often through dense forests and marshy areas.

It would be advisable for future monitoring studies to be conducted in the spring or early summer when the water level is higher and the flow rate faster. Candidate streams to study at this time include: Stokes River, Brinkman's Creek, Sideroad Creek, and Old Woman's River. All of these streams were evaluated for potential reference sites during August of 2003 however, the water level in the streams was insufficient for benthic collection. The upper reaches of Stokes

River could be studied near Cape Chin, off of the East Road. Potential test sites could be established in Stokes Bay near the Lake Huron shoreline and upstream where the river runs through pastureland. Two land owners that may be willing to provide access through their property in this area are Don Ceaser and Richard McLay. Another potential test site on the Stokes River would be behind the Municipal office on Lindsay Road #5. Sideroad Creek could be studied upstream from Dorcas Bay Road where there is a higher proportion of forested area. Old Woman's River flows through open, agricultural land and is used as an irrigation source by many farmers. However, there are some areas that have a high proportion of forested area and test sites could be placed upstream where the river crosses the Stokes Bay Road. Bruce Atkinson may be willing to provide access to the river in this area in order for test sites to be added to the monitoring program.

The continuation of this valuable monitoring program is essential to the understanding of aquatic ecosystems on the Bruce Peninsula. The establishment of reference sites will provide standards in which to compare test sites to in future monitoring years. Following the establishment of additional reference sites, and latter test sites, trends regarding the health of the streams can be identified.

REFERENCES

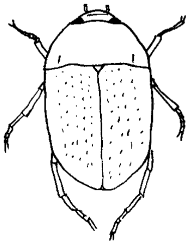
Jones, C., Somers, K., Reid, R., Fletcher, R., Winte, J., Reynoldson, T., Craig, B. (2003). Ontario Benthos Biomonitoring Network Protocol Manual (Draft). Ontario Ministry of Environment and Environment Canada: Ontario.

Jones, C. Benthic Biomonitoring Scientist, Dorset Environmental Science Centre, Ontario. Personal communication through email. Email Dates: Oct. 7, Nov. 6&7, 2003.

APPENDIX 1: Recommended Field Sheet

The recommended field sheet is for recording site location, date, sampling team, sampling method and habitat information is shown on the following pages (Jones et al., 2003).

Ontario Benthos Biomonitoring Network Field Sheet



Waterbody Name
Location description
Station #
Lat
Long
Agency
Investigators
Date & Time
Weather conditions
Elevation (m asl):
Water Temperature
Air temperature:
DO (mg/l)
Ph
Conductivity (uS/cm)

Site description and map - draw a map of site and indicate areas sampled or attach photograph
Note width and depth of river. Show north arrow.

Collection Protocol (circle Appropriate)

Traveling Kick:	Corer	Grab Sample:	Artificial	Other:
Transect		Ekman Dredge	Substrate	
Riffle Only		Ponar Grab		

	Replicate 1	Replicate 2	Replicate 3	Replicate UTMs (Note Datum)
# Transects Used:				1
# samples pooled/replicate				
Total distance traveled				2
Total sampling time				

(Enter max depth (m), hydraulic head at thalweg (mm), wetted width, and distance to transect from transect 1)

Replicate 1

Transects	Max. Depth (m)	Wetted Width (m)	Hydraulic Head (mm)	Transect Spacing (m)
1				
2				
3				
4				

Replicate 2

Transects	Max. Depth (m)	Wetted Width (m)	Hydraulic Head (mm)	Transect Spacing (m)
1				
2				
3				
4				

Replicate 3

Transects	Max. Depth (m)	Wetted Width (m)	Hydraulic Head (mm)	Transect Spacing (m)
1				
2				
3				
4				

Replicate 4

Transects	Max. Depth (m)	Wetted Width (m)	Hydraulic Head (mm)	Transect Spacing (m)
1				
2				
3				
4				

CANDIDATE REFERENCE SITE (MINIMALLY IMPACTED)? YES NO

Substrate Class	Description
1	Clay (hard pan)
2	Silt (gritty, <0.06 mm particle diameter)
3	Sand (grainy, 0.06-2 mm particle diameter)
4	Gravel (2-65 mm)
5	Cobble (65-250 mm)
6	Boulder (>250 mm)
7	Bed Rock

Areal Coverage Estimates (%)

	Replicate 1	Replicate 2	Replicate 3
Macrophytes			
Woody debris			
Detritus			

Additional Notes on Substrate:

Enter dominant substrate class and second dominant class for each replicate

	Replicate 1	Replicate 2	Replicate 3
Dominant			
2nd Dominant			

Catchment Physiography (drainage area to sampled site):

Catchment area (km^2):
Bankfull Width (m):
Flow (cms):
Forest Cover (%):
Wetted Width (m):
Impervious (%):
Stream Order:
"Well drained" (%):
Stream Length (m):

Riparian vegetation - indicate all types present and record dominant type

Trees Shrubs Grasses % canopy cover:

other ____________________ dominant type ____________________

Aquatic vegetation - indicate types and record dominant type 1) Macrophytes, 2) Algae

1) ☐ emergent ☐ submergent ☐ rooted floating ☐ free floating

2) ☐ floating algae ☐ attached algae ☐ filaments ☐ slimes or crusts

dominant type

(Note predominant surrounding landscape and record any evidence of human impact

River characterization

perennial intermittent warmwater coldwater

	Replicate 1	Replicate 2	Replicate 3
Sub-sampling: Estimate portion of sample (or pooled samples) picked per replicate to obtain ~100 count	0.3	0.4	0.5

SUBSAMPLING Marchant Method Teaspoon Method

Proportion of sample processed:

PICKING LIVE PRESERVED MICROSCOPE AIDED

Sample Archive:

Notes:

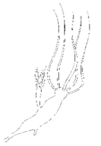
General Comments:

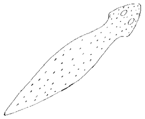
APPENDIX 2: Recommended Taxa Tally Sheet

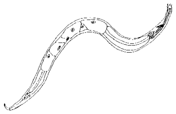
The taxa tally sheet on the following page is used to identify to the minimum taxonomic level recommended by the Ontario Benthos Biomonitoring Network and to keep track of benthos counts during sample picking (Jones et al., 2003).

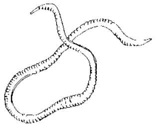
Lake/Stream/Wetland Name: ________________________________ Site Code: _____________ Date (mm/dd/yyyy): ___________________

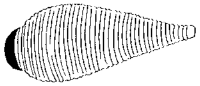
Sampling Team: ____ Replicate #: ______ # of Bottles (archiving): _________

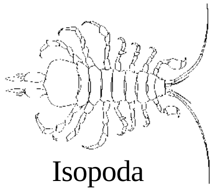

Coelenterata
(Hydras)

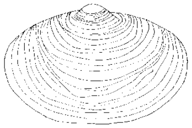

Turbellaria
(Flatworms)

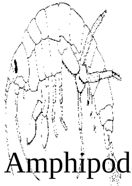

Nematoda
(Roundworms)

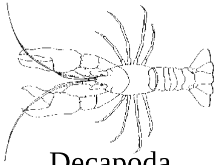

Oligochaeta
(Aquatic Earthworms)

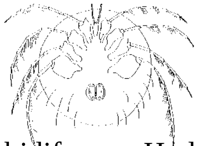

Hirudinea
(Leeches)

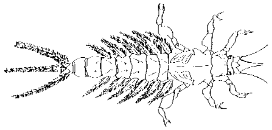

Isopoda
(Sow Bugs)


Pelecypoda
(Clams)

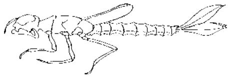

Amphipoda
(Scuds)

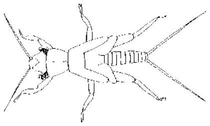

Decapoda
(Crayfish)

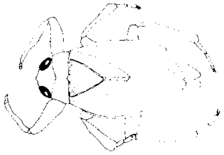

Trombidiformes-Hydracarina
(Mites)

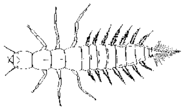

Ephemeroptera
(Mayflies)

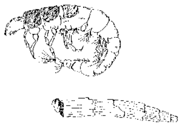

Anisoptera
(Dragonflies)

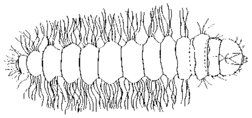

Zygoptera
(Damselflies)

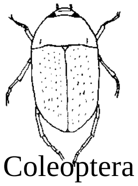

Plecoptera
(Stoneflies)

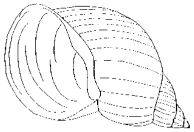

Hemiptera
(True Bugs)


Megaloptera
(Fishflies, Alderflies)


Trichoptera
(Caddisflies)

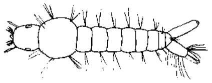

Lepidoptera
(Aquatic Moths)

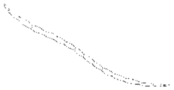

Coleoptera
(Beetles)

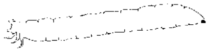

Gastropoda
(Snails, limpets)


Chironomidae
(Midges)

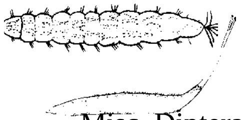

Tabanidae
(Horse and Deer Flies)


Culicidae
(Mosquitos)


Ceratopogonidae
(No-see-ums)

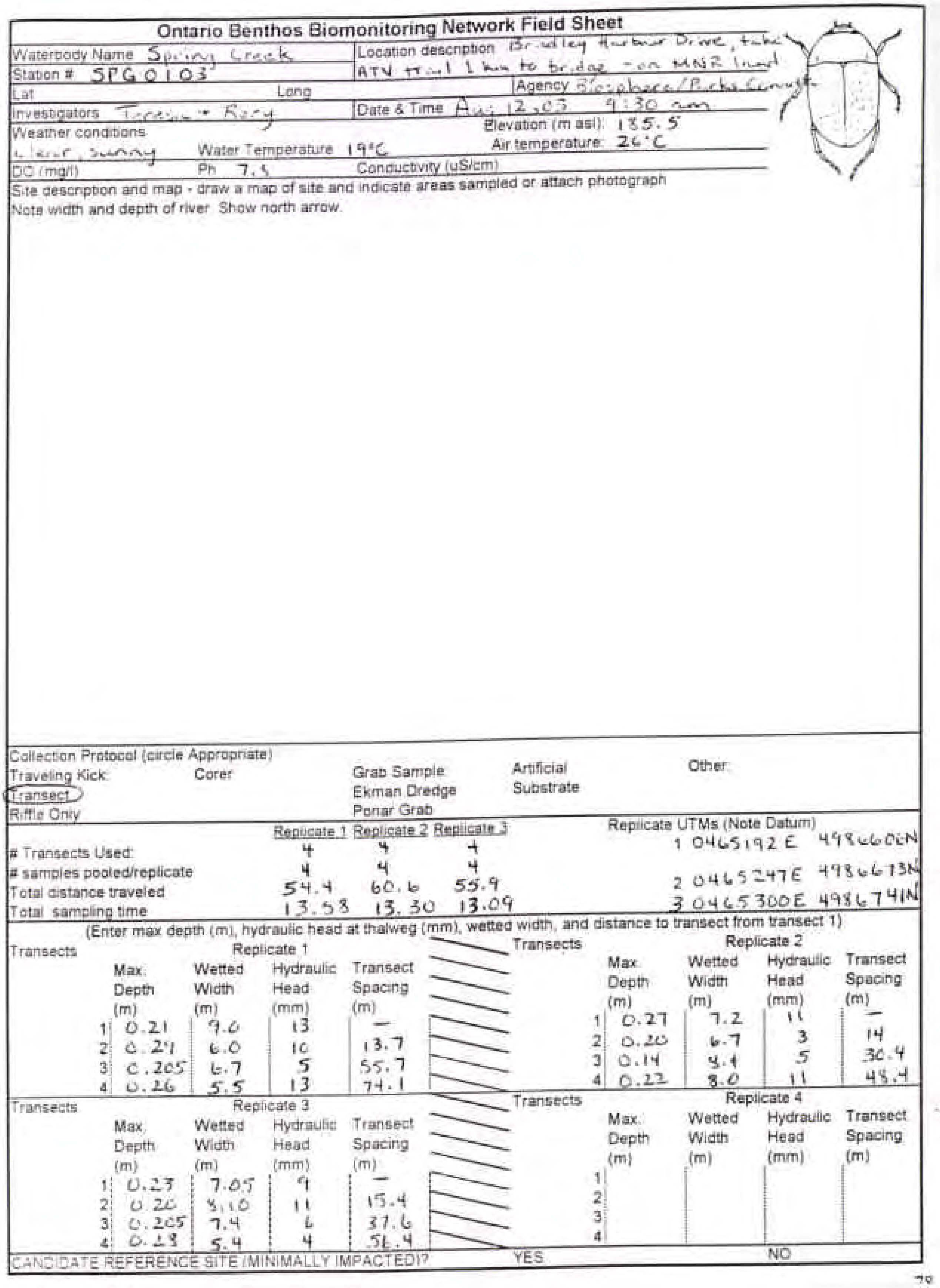

Tipulidae
(Crane Flies)


Simuliidae
(Black Flies)


Misc. Diptera
(Misc. True Flies)

Ontario Benthos Biomonitoring Network Revised May 2003

APENDIX 3: Completed Field Sheets for each of the Four Sites



Ontario Benthos Biomonitoring Network Field Sheet

Waterbody Name Spring Creek

Location description Bradley Harbour Drive, take ATV trail 1 km to bridge - on MNR land

Station # SPG0103

Lat

Long

Agency Biosphere/Parks Canada

Investigators Teresa + Rory

Date & Time Aug 12, 03 9:30 am

Weather conditions clear, sunny

Elevation (m asl): 135.5

Water Temperature 19°C

Air temperature: 26°C

DO (mg/l)

Ph 7.5

Conductivity (uS/cm)

Site description and map - draw a map of site and indicate areas sampled or attach photograph Note width and depth of river. Show north arrow.

Collection Protocol (circle Appropriate)

Traveling Kick: [✓ Transect] Riffle Only

Corer

Grab Sample Ekman Dredge Ponar Grab

Artificial Substrate

Other:

	Replicate 1	Replicate 2	Replicate 3
# Transects Used:	4	4	4
# samples pooled/replicate	4	4	4
Total distance traveled	54.4	60.6	55.9
Total sampling time	13.58	13.30	13.09

Replicate UTMs (Note Datum)

1 0465192E 4986606N

2 0465247E 4986673N

3 0465300E 4986741N

(Enter max depth (m), hydraulic head at thalweg (mm), wetted width, and distance to transect from transect 1)

Replicate 1

Transects	Max. Depth (m)	Wetted Width (m)	Hydraulic Head (mm)	Transect Spacing (m)
1	0.21	9.6	13	—
2	0.29	6.0	10	13.7
3	0.205	6.7	5	55.7
4	0.26	5.5	13	74.1

Replicate 2

Transects	Max. Depth (m)	Wetted Width (m)	Hydraulic Head (mm)	Transect Spacing (m)
1	0.27	7.2	11	—
2	0.20	6.7	3	14
3	0.14	8.4	5	30.4
4	0.22	8.0	11	48.4

Replicate 3

Transects	Max. Depth (m)	Wetted Width (m)	Hydraulic Head (mm)	Transect Spacing (m)
1	0.23	7.05	9	—
2	0.20	8.10	11	15.4
3	0.205	7.4	6	37.6
4	0.23	5.4	4	56.4

Replicate 4

Transects	Max. Depth (m)	Wetted Width (m)	Hydraulic Head (mm)	Transect Spacing (m)
1				
2				
3				
4				

CANDIDATE REFERENCE SITE (MINIMALLY IMPACTED)? YES NO

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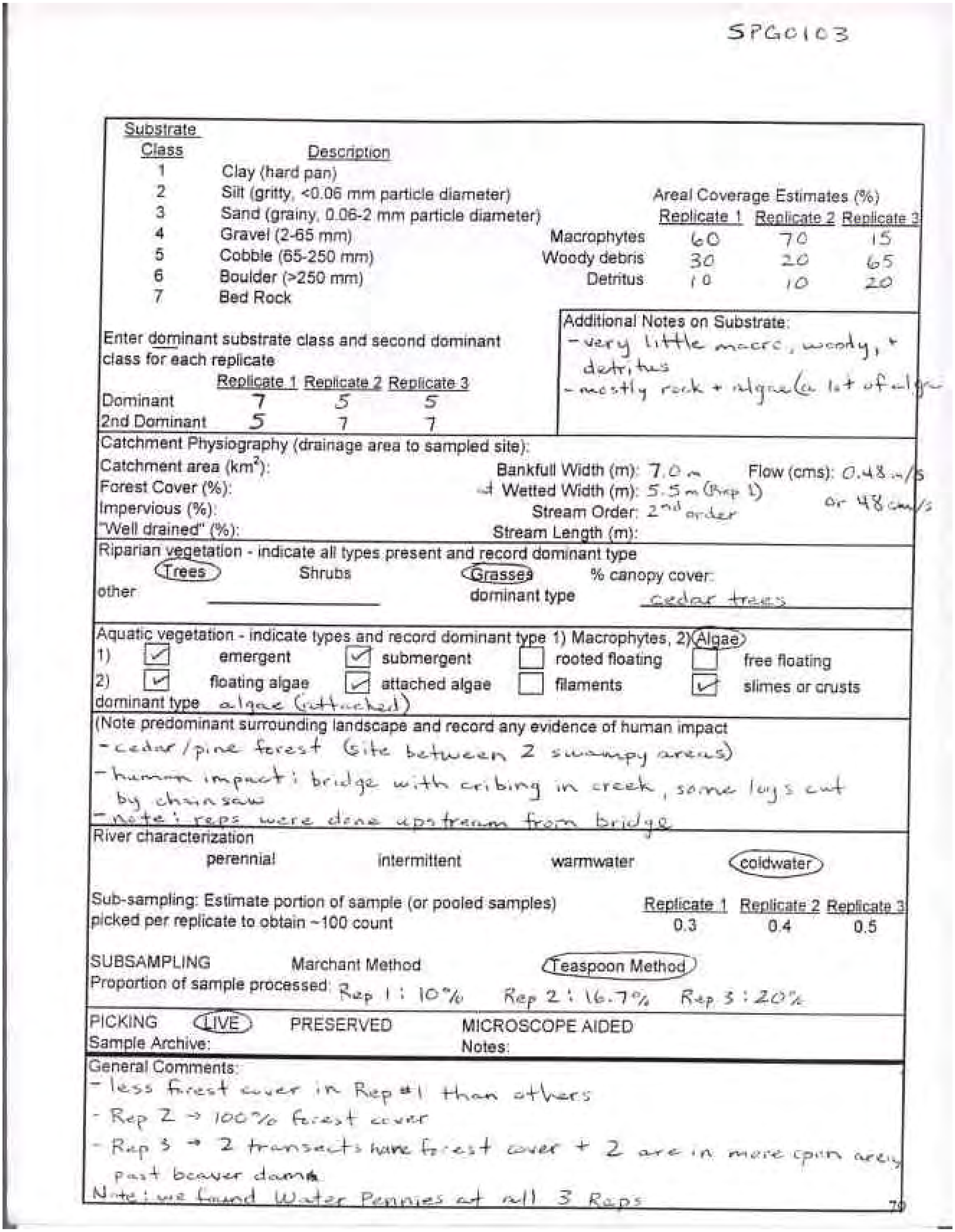
Spring Creek Site 1, Page 2



SPG0103

Substrate Class	Description
1	Clay (hard pan)
2	Silt (gritty, <0.06 mm particle diameter)
3	Sand (grainy, 0.06-2 mm particle diameter)
4	Gravel (2-65 mm)
5	Cobble (65-250 mm)
6	Boulder (>250 mm)
7	Bed Rock

Areal Coverage Estimates (%)

	Replicate 1	Replicate 2	Replicate 3
Macrophytes	60	70	15
Woody debris	30	20	65
Detritus	10	10	20

Enter dominant substrate class and second dominant class for each replicate

	Replicate 1	Replicate 2	Replicate 3
Dominant	7	5	5
2nd Dominant	5	7	7

Additional Notes on Substrate:
- very little macro, woody, + detritus
- mostly rock + algae (a lot of algae

Catchment Physiography (drainage area to sampled site):

Catchment area (km²):
Forest Cover (%):
Impervious (%):
"Well drained" (%):
Bankfull Width (m): 7.0 m
Wetted Width (m): 5.5 m (Rep 1)
Stream Order: 2nd order
Stream Length (m):
Flow (cms): 0.48 m/s or 48 cm/s

Riparian vegetation - indicate all types present and record dominant type

[✓ Trees] Shrubs [✓ Grasses] % canopy cover:
other ______________ dominant type cedar trees

Aquatic vegetation - indicate types and record dominant type 1) Macrophytes, 2) [✓ Algae]

1) ☑ emergent ☑ submergent ☐ rooted floating ☐ free floating
2) ☑ floating algae ☑ attached algae ☐ filaments ☑ slimes or crusts

dominant type algae (attached)

(Note predominant surrounding landscape and record any evidence of human impact
- cedar/pine forest (site between 2 swampy areas)
- human impact: bridge with cribing in creek, some logs cut by chainsaw
- note: reps were done upstream from bridge

River characterization

perennial intermittent warmwater [✓ coldwater]

Sub-sampling: Estimate portion of sample (or pooled samples) picked per replicate to obtain ~100 count

Replicate 1	Replicate 2	Replicate 3
0.3	0.4	0.5

SUBSAMPLING Marchant Method [✓ Teaspoon Method]
Proportion of sample processed: Rep 1: 10% Rep 2: 16.7% Rep 3: 20%

PICKING [✓ LIVE] PRESERVED MICROSCOPE AIDED
Sample Archive: Notes:

General Comments:
- less forest cover in Rep #1 than others
- Rep 2 → 100% forest cover
- Rep 3 → 2 transects have forest cover + 2 are in more open area past beaver dam
Note: we found Water Pennies at all 3 Reps

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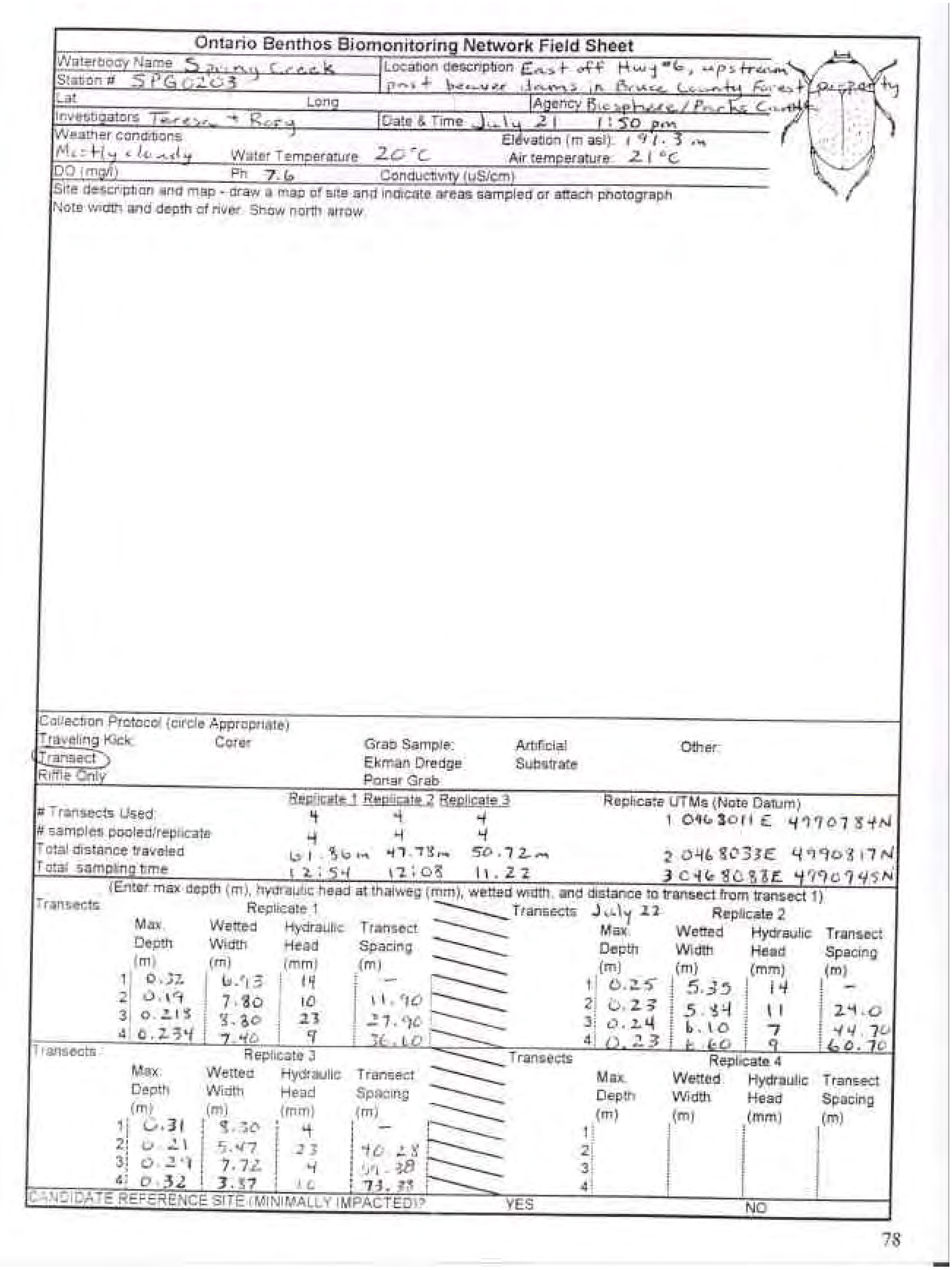
Spring Creek Site 2, page 1



Ontario Benthos Biomonitoring Network Field Sheet

Waterbody Name Spring Creek
Station # SPG0203
Location description East off Hwy #6, upstream past beaver dams in Bruce County Forest property
Lat
Long
Agency Biosphere/Parks Canada
Investigators Teresa + Rory
Date & Time July 21 1:50 pm
Weather conditions Mostly cloudy
Elevation (m asl): 191.3 m
Water Temperature 20°C
Air temperature: 21°C
DO (mg/l)
Ph 7.6
Conductivity (uS/cm)

Site description and map - draw a map of site and indicate areas sampled or attach photograph
Note width and depth of river. Show north arrow.

Collection Protocol (circle Appropriate)

Traveling Kick
[✓ Transect]
Riffle Only
Corer
Grab Sample:
Ekman Dredge
Ponar Grab
Artificial Substrate
Other:

	Replicate 1	Replicate 2	Replicate 3
# Transects Used:	4	4	4
# samples pooled/replicate	4	4	4
Total distance traveled	61.86m	47.78m	50.72m
Total sampling time	12:54	12:08	11.22

Replicate UTMs (Note Datum)
1 0468011E 4970784N
2 0468033E 4990817N
3 0468088E 4990745N

(Enter max depth (m), hydraulic head at thalweg (mm), wetted width, and distance to transect from transect 1)

Transects — Replicate 1

Transects	Max. Depth (m)	Wetted Width (m)	Hydraulic Head (mm)	Transect Spacing (m)
1	0.32	6.93	14	–
2	0.19	7.80	10	11.90
3	0.218	8.80	23	27.90
4	0.234	7.40	9	36.10

Transects July 22 — Replicate 2

Transects	Max. Depth (m)	Wetted Width (m)	Hydraulic Head (mm)	Transect Spacing (m)
1	0.25	5.35	14	–
2	0.23	5.34	11	24.0
3	0.24	6.10	7	44.70
4	0.23	6.60	9	60.70

Transects — Replicate 3

Transects	Max. Depth (m)	Wetted Width (m)	Hydraulic Head (mm)	Transect Spacing (m)
1	0.31	8.30	4	–
2	0.21	5.47	23	40.28
3	0.29	7.72	4	64.38
4	0.32	3.37	10	73.38

Transects — Replicate 4

Transects	Max. Depth (m)	Wetted Width (m)	Hydraulic Head (mm)	Transect Spacing (m)
1				
2				
3				
4				

CANDIDATE REFERENCE SITE (MINIMALLY IMPACTED)? YES NO

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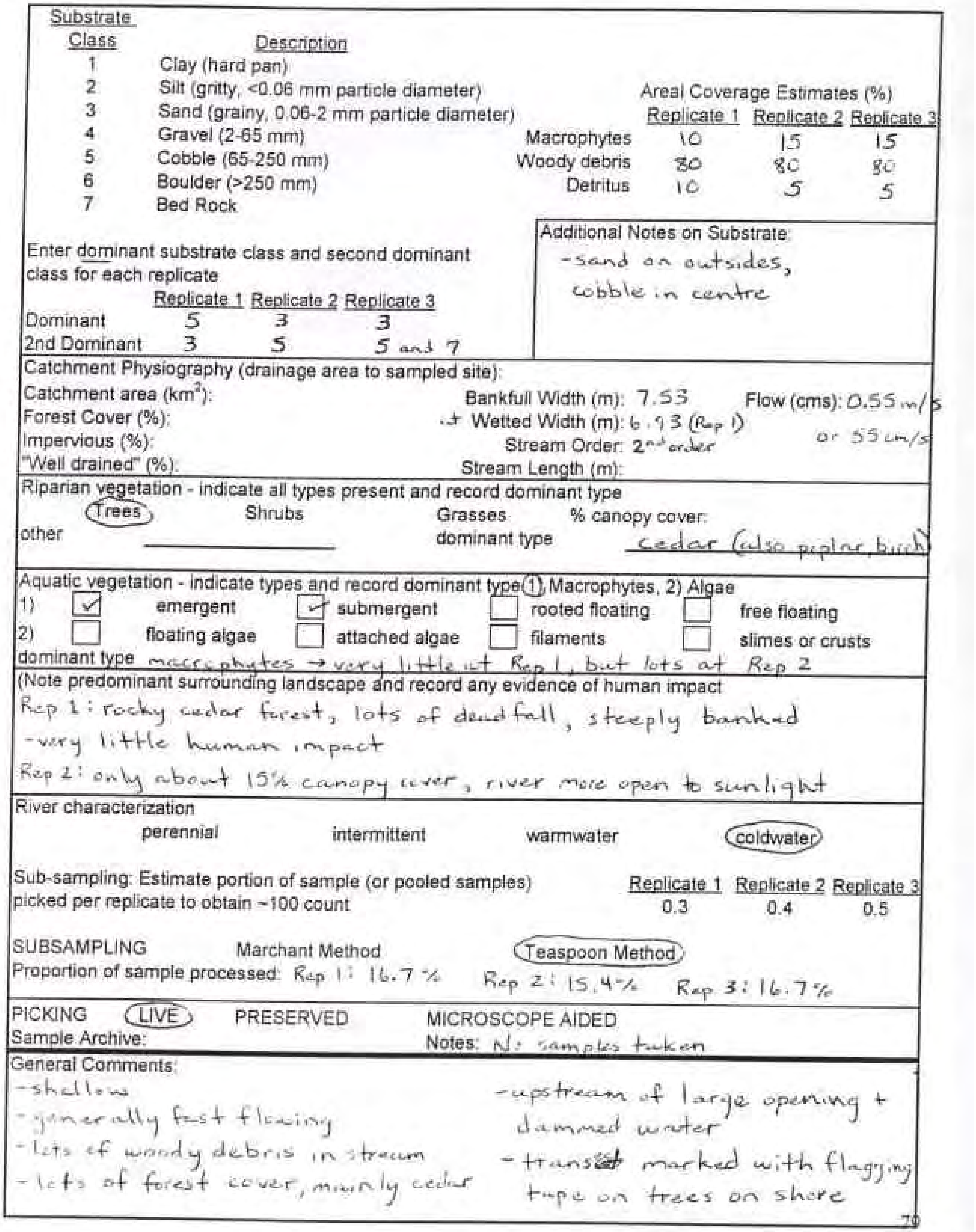
Spring Creek Site 2, page 2



Substrate Class	Description
1	Clay (hard pan)
2	Silt (gritty, <0.06 mm particle diameter)
3	Sand (grainy, 0.06-2 mm particle diameter)
4	Gravel (2-65 mm)
5	Cobble (65-250 mm)
6	Boulder (>250 mm)
7	Bed Rock

Areal Coverage Estimates (%)

	Replicate 1	Replicate 2	Replicate 3
Macrophytes	10	15	15
Woody debris	80	80	80
Detritus	10	5	5

Enter dominant substrate class and second dominant class for each replicate

	Replicate 1	Replicate 2	Replicate 3
Dominant	5	3	3
2nd Dominant	3	5	5 and 7

Additional Notes on Substrate:
-sand on outsides,
cobble in centre

Catchment Physiography (drainage area to sampled site):

Catchment area (km^2):
Forest Cover (%):
Impervious (%):
"Well drained" (%):
Bankfull Width (m): 7.53
+ Wetted Width (m): 6.93 (Rep 1)
Stream Order: 2nd order
Stream Length (m):
Flow (cms): 0.55 m/s or 55 cm/s

Riparian vegetation - indicate all types present and record dominant type

[✓ Trees] Shrubs Grasses
% canopy cover:
other ____________
dominant type cedar (also poplar, birch

Aquatic vegetation - indicate types and record dominant type [✓ 1)] Macrophytes, 2) Algae

1) ☑ emergent ☑ submergent ☐ rooted floating ☐ free floating
2) ☐ floating algae ☐ attached algae ☐ filaments ☐ slimes or crusts

dominant type macrophytes → very little at Rep 1, but lots at Rep 2

(Note predominant surrounding landscape and record any evidence of human impact

Rep 1: rocky cedar forest, lots of deadfall, steeply banked
-very little human impact
Rep 2: only about 15% canopy cover, river more open to sunlight

River characterization

perennial intermittent warmwater [✓ coldwater]

Sub-sampling: Estimate portion of sample (or pooled samples) picked per replicate to obtain ~100 count

Replicate 1	Replicate 2	Replicate 3
0.3	0.4	0.5

SUBSAMPLING Marchant Method [✓ Teaspoon Method]

Proportion of sample processed: Rep 1: 16.7 % Rep 2: 15.4% Rep 3: 16.7%

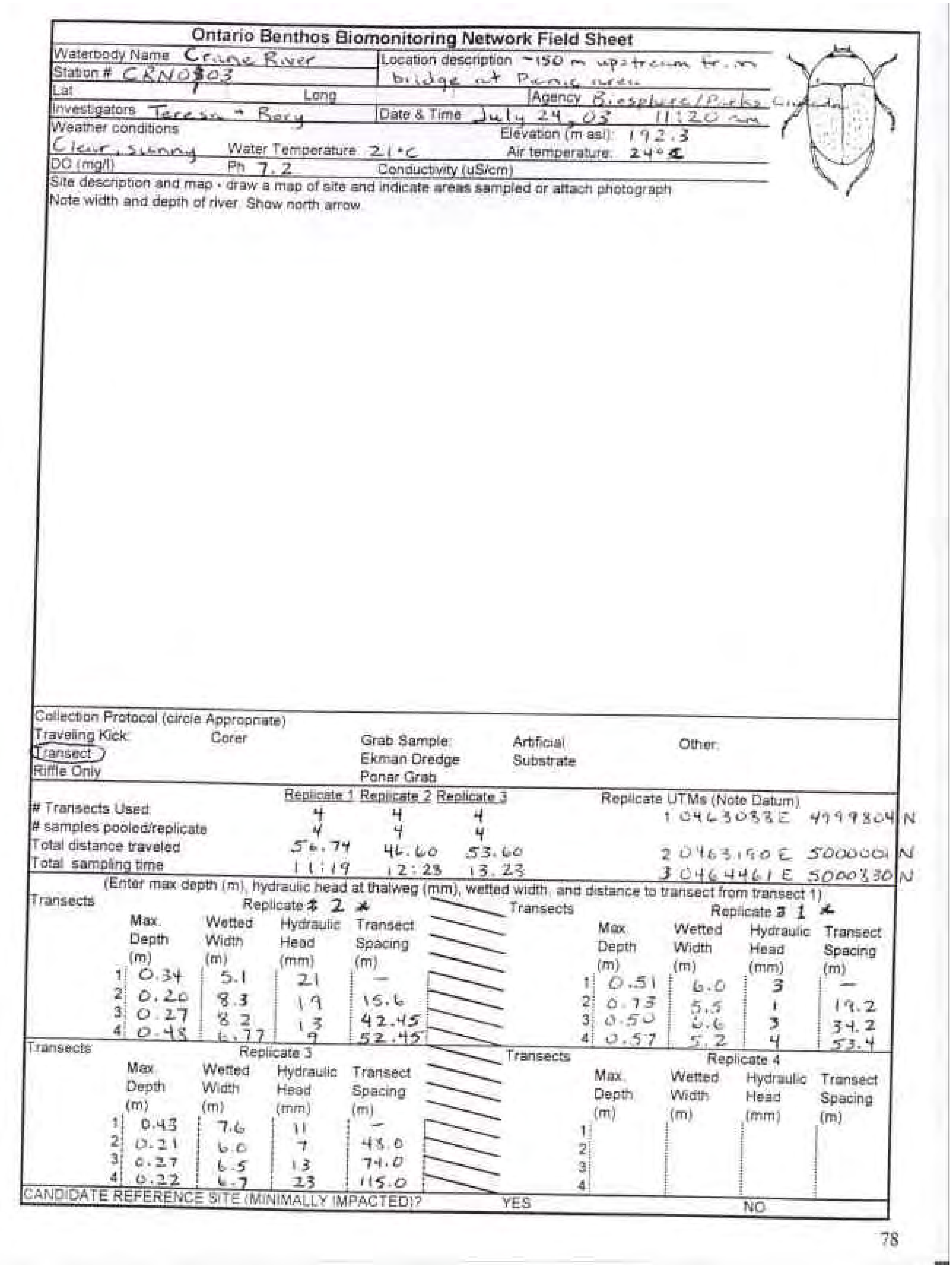
PICKING [✓ LIVE] PRESERVED MICROSCOPE AIDED

Sample Archive:
Notes: No samples taken

General Comments:

-shallow
-generally fast flowing
-lots of woody debris in stream
-lots of forest cover, mainly cedar
-upstream of large opening + dammed water
-transect marked with flagging tape on trees on shore

Crane River Site 1. page 1



Ontario Benthos Biomonitoring Network Field Sheet

Waterbody Name Crane River
Station # CRN0$03
Lat
Long
Investigators Teresa + Rory
Weather conditions Clear, sunny
DO (mg/l)
Location description ~150 m upstream from bridge at Picnic area
Agency Biosphere/Parks Canada
Date & Time July 24, 03 11:20 am
Elevation (m asl): 192.3
Water Temperature 21°C
Air temperature: 24°C
Ph 7.2
Conductivity (uS/cm)

Site description and map - draw a map of site and indicate areas sampled or attach photograph
Note width and depth of river. Show north arrow.

Collection Protocol (circle Appropriate)
Traveling Kick: [✓ Transect] Riffle Only
Corer
Grab Sample: Ekman Dredge Ponar Grab
Artificial Substrate
Other:

	Replicate 1	Replicate 2	Replicate 3
# Transects Used	4	4	4
# samples pooled/replicate	4	4	4
Total distance traveled	56.74	46.60	53.60
Total sampling time	11:19	12:23	13.23

Replicate UTMs (Note Datum)
1 0463083E 4999804 N
2 0463150E 5000001 N
3 0464461 E 5000330 N

(Enter max depth (m), hydraulic head at thalweg (mm), wetted width, and distance to transect from transect 1)

Transects — Replicate # 2 *

	Max. Depth (m)	Wetted Width (m)	Hydraulic Head (mm)	Transect Spacing (m)
1	0.34	5.1	21	—
2	0.20	8.3	19	15.6
3	0.27	8.2	13	42.45
4	0.48	6.77	9	52.45

Transects — Replicate # 1 *

	Max. Depth (m)	Wetted Width (m)	Hydraulic Head (mm)	Transect Spacing (m)
1	0.51	6.0	3	—
2	0.73	5.5	1	19.2
3	0.50	6.6	3	34.2
4	0.57	5.2	4	53.4

Transects — Replicate 3

	Max. Depth (m)	Wetted Width (m)	Hydraulic Head (mm)	Transect Spacing (m)
1	0.43	7.6	11	—
2	0.21	6.0	7	43.0
3	0.27	6.5	13	74.0
4	0.22	6.7	23	115.0

Transects — Replicate 4

	Max. Depth (m)	Wetted Width (m)	Hydraulic Head (mm)	Transect Spacing (m)
1				
2				
3				
4				

CANDIDATE REFERENCE SITE (MINIMALLY IMPACTED)? YES NO

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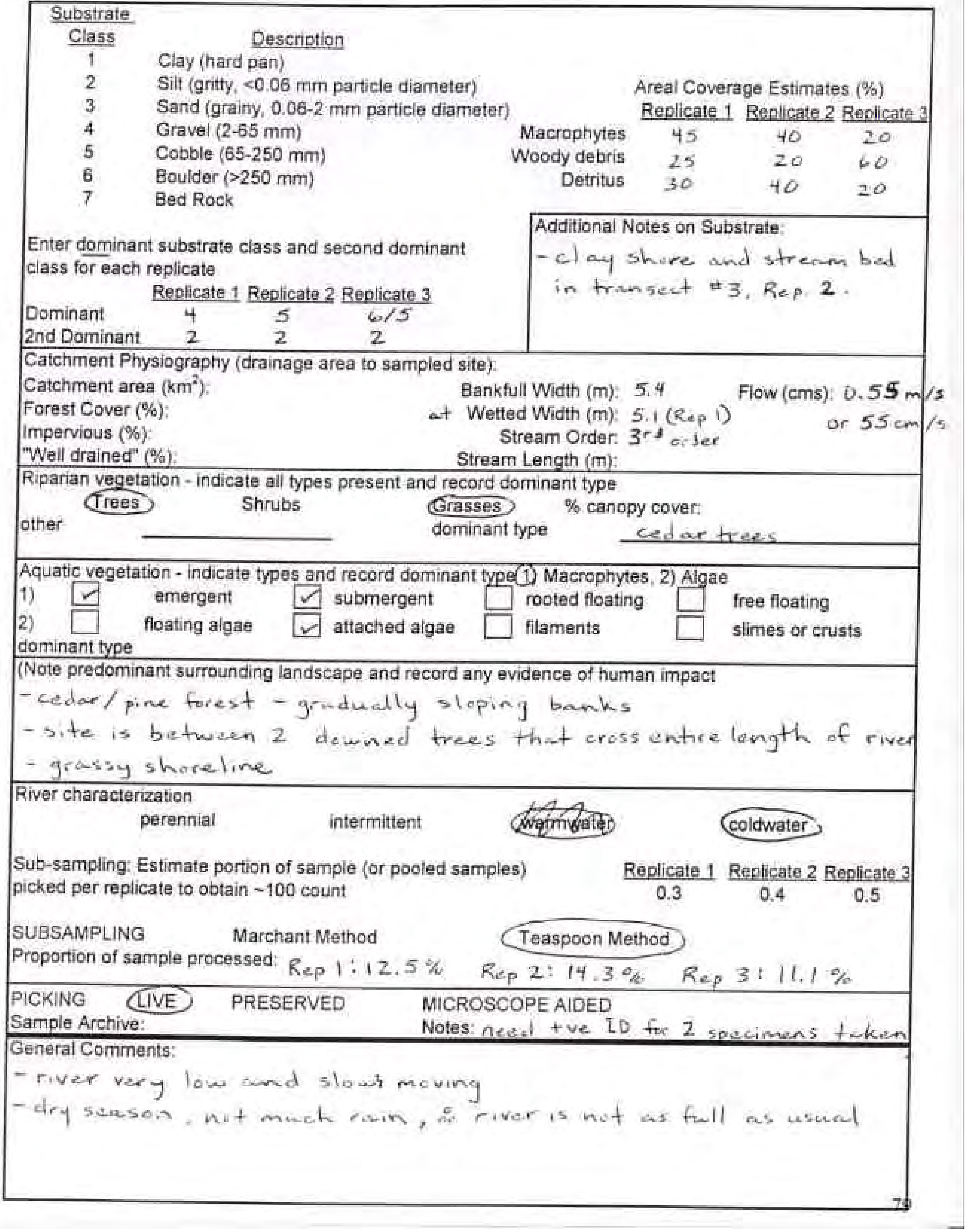
Crane River Site 1, page 2



Substrate Class	Description
1	Clay (hard pan)
2	Silt (gritty, <0.06 mm particle diameter)
3	Sand (grainy, 0.06-2 mm particle diameter)
4	Gravel (2-65 mm)
5	Cobble (65-250 mm)
6	Boulder (>250 mm)
7	Bed Rock

Areal Coverage Estimates (%)

	Replicate 1	Replicate 2	Replicate 3
Macrophytes	45	40	20
Woody debris	25	20	60
Detritus	30	40	20

Enter dominant substrate class and second dominant class for each replicate

	Replicate 1	Replicate 2	Replicate 3
Dominant	4	5	6/5
2nd Dominant	2	2	2

Additional Notes on Substrate:

- clay shore and stream bed in transect #3, Rep. 2.

Catchment Physiography (drainage area to sampled site):

Catchment area (km^2):

Forest Cover (%):

Impervious (%):

"Well drained" (%):

Bankfull Width (m): 5.4

at Wetted Width (m): 5.1 (Rep 1)

Stream Order: 3rd order

Stream Length (m):

Flow (cms): 0.55 m/s or 55 cm/s

Riparian vegetation - indicate all types present and record dominant type

[✓ Trees] Shrubs [✓ Grasses] % canopy cover:

other __________ dominant type cedar trees

Aquatic vegetation - indicate types and record dominant type [✓ 1)] Macrophytes, 2) Algae

1) ☑ emergent ☑ submergent ☐ rooted floating ☐ free floating

2) ☐ floating algae ☑ attached algae ☐ filaments ☐ slimes or crusts

dominant type

(Note predominant surrounding landscape and record any evidence of human impact

- cedar / pine forest - gradually sloping banks
- site is between 2 downed trees that cross entire length of river
- grassy shoreline

River characterization

perennial intermittent ~~warmwater~~ [✓ coldwater]

Sub-sampling: Estimate portion of sample (or pooled samples) picked per replicate to obtain ~100 count

Replicate 1	Replicate 2	Replicate 3
0.3	0.4	0.5

SUBSAMPLING Marchant Method [✓ Teaspoon Method]

Proportion of sample processed: Rep 1: 12.5% Rep 2: 14.3% Rep 3: 11.1%

PICKING [✓ LIVE] PRESERVED MICROSCOPE AIDED

Sample Archive:

Notes: need +ve ID for 2 specimens taken

General Comments:

- river very low and slow moving
- dry season, not much rain, so river is not as full as usual

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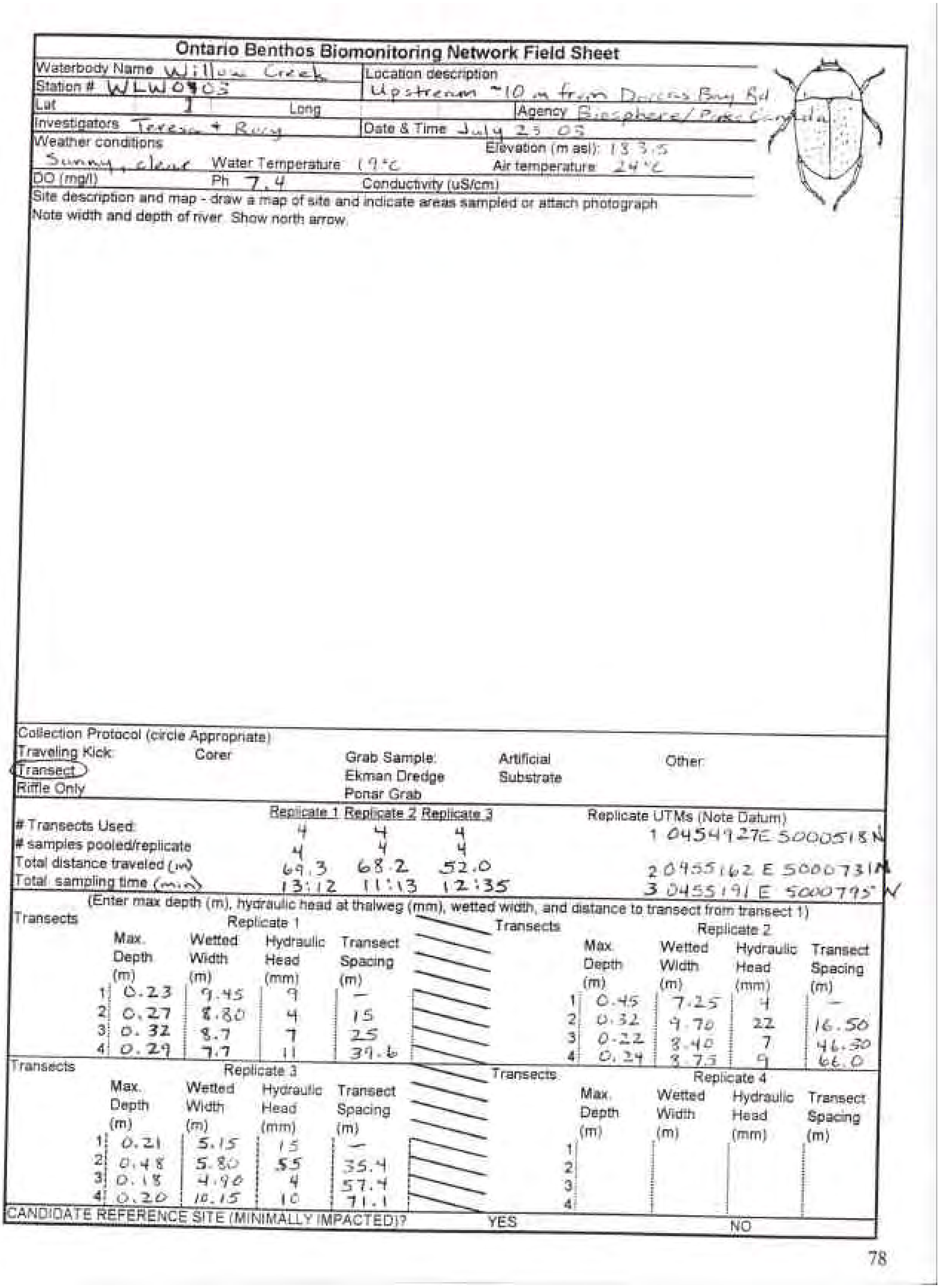
Willow Creek Site 1, page 1



Ontario Benthos Biomonitoring Network Field Sheet

Waterbody Name Willow Creek

Station # WLW0905

Location description Upstream ~10 m from Dorcas Bay Rd

Lat Long

Agency Biosphere/Parks Canada

Investigators Teresa + Rudy

Date & Time July 25 05

Weather conditions Sunny, clear

Elevation (m asl): 133.5

Water Temperature 19°C

Air temperature 24°C

DO (mg/l)

Ph 7.4

Conductivity (uS/cm)

Site description and map - draw a map of site and indicate areas sampled or attach photograph
Note width and depth of river. Show north arrow.

Collection Protocol (circle Appropriate)

Traveling Kick: [✓ Transect] Riffle Only

Corer

Grab Sample: Ekman Dredge Ponar Grab

Artificial Substrate

Other:

	Replicate 1	Replicate 2	Replicate 3
# Transects Used	4	4	4
# samples pooled/replicate	4	4	4
Total distance traveled (m)	69.3	68.2	52.0
Total sampling time (min)	13:12	11:13	12:35

Replicate UTMs (Note Datum)

1 0454927E 5000518N

2 0455162 E 5000731N

3 0455191 E 5000795 N

(Enter max depth (m), hydraulic head at thalweg (mm), wetted width, and distance to transect from transect 1)

Transects — Replicate 1

Transects	Max. Depth (m)	Wetted Width (m)	Hydraulic Head (mm)	Transect Spacing (m)
1	0.23	9.45	9	—
2	0.27	8.80	4	15
3	0.32	8.7	7	25
4	0.29	7.7	11	39.6

Transects — Replicate 2

Transects	Max. Depth (m)	Wetted Width (m)	Hydraulic Head (mm)	Transect Spacing (m)
1	0.45	7.25	4	—
2	0.32	9.70	22	16.50
3	0.22	8.40	7	46.30
4	0.24	8.75	9	66.0

Transects — Replicate 3

Transects	Max. Depth (m)	Wetted Width (m)	Hydraulic Head (mm)	Transect Spacing (m)
1	0.21	5.15	15	—
2	0.48	5.80	55	35.4
3	0.18	4.90	4	57.4
4	0.20	10.15	10	71.1

Transects — Replicate 4

Transects	Max. Depth (m)	Wetted Width (m)	Hydraulic Head (mm)	Transect Spacing (m)
1				
2				
3				
4				

CANDIDATE REFERENCE SITE (MINIMALLY IMPACTED)? YES NO

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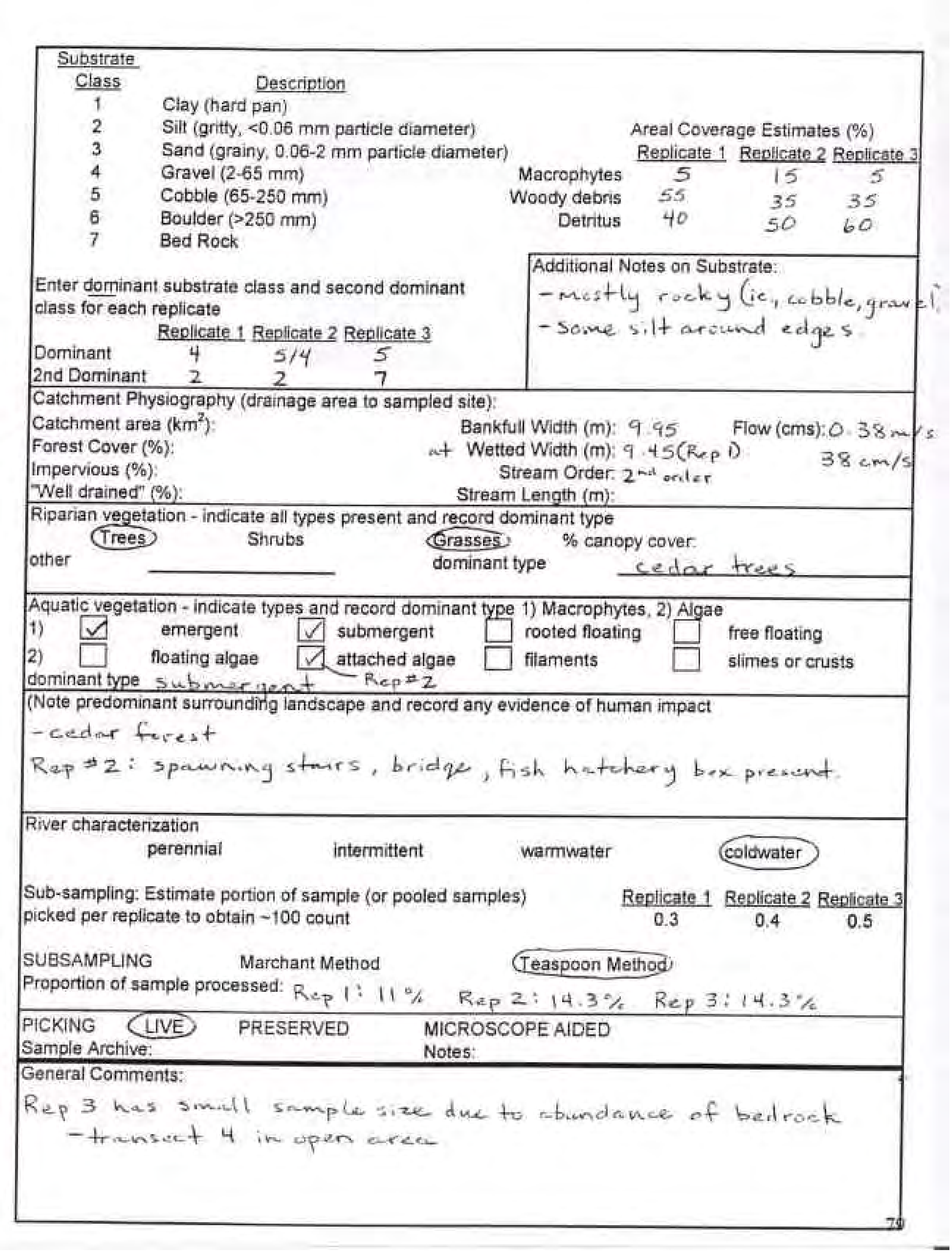
Willow Creek Site 1, page 2



Substrate Class	Description
1	Clay (hard pan)
2	Silt (gritty, <0.06 mm particle diameter)
3	Sand (grainy, 0.06-2 mm particle diameter)
4	Gravel (2-65 mm)
5	Cobble (65-250 mm)
6	Boulder (>250 mm)
7	Bed Rock

Areal Coverage Estimates (%)

	Replicate 1	Replicate 2	Replicate 3
Macrophytes	5	15	5
Woody debris	55	35	35
Detritus	40	50	60

Enter dominant substrate class and second dominant class for each replicate

	Replicate 1	Replicate 2	Replicate 3
Dominant	4	5/4	5
2nd Dominant	2	2	7

Additional Notes on Substrate:
- mostly rocky (ie, cobble, gravel)
- some silt around edges

Catchment Physiography (drainage area to sampled site):

Catchment area (km²):

Forest Cover (%):

Impervious (%):

"Well drained" (%):

Bankfull Width (m): 9.95

at Wetted Width (m): 9.45 (Rep 1)

Stream Order: 2nd order

Stream Length (m):

Flow (cms): 0.38 m/s

38 cm/s

Riparian vegetation - indicate all types present and record dominant type

[✓ Trees] Shrubs [✓ Grasses] % canopy cover:

other ____________ dominant type cedar trees

Aquatic vegetation - indicate types and record dominant type 1) Macrophytes, 2) Algae

1) ☑ emergent ☑ submergent ☐ rooted floating ☐ free floating

2) ☐ floating algae ☑ attached algae ☐ filaments ☐ slimes or crusts

Rep#2

dominant type submergent

(Note predominant surrounding landscape and record any evidence of human impact

- cedar forest

Rep#2: spawning stairs, bridge, fish hatchery box present.

River characterization

perennial intermittent warmwater [✓ coldwater]

Sub-sampling: Estimate portion of sample (or pooled samples) picked per replicate to obtain ~100 count

Replicate 1	Replicate 2	Replicate 3
0.3	0.4	0.5

SUBSAMPLING Marchant Method [✓ Teaspoon Method]

Proportion of sample processed: Rep 1: 11% Rep 2: 14.3% Rep 3: 14.3%

PICKING [✓ LIVE] PRESERVED MICROSCOPE AIDED

Sample Archive:

Notes:

General Comments:

Rep 3 has small sample size due to abundance of bedrock
- transect 4 in open area

APPENDIX 4: Parameter Descriptions

Parameter Descriptions for Stream Sites (Jones, personal comm.)

Drainage Area (DA): Area of delineated drainage basin. Also called watershed.
Perimeter (P): Length of the watershed boundary line.
Stream Order: A classification system for stream size, generally applied using topographic maps.
% Water and Wetland Cover (ACLS): Percentage of area covered by lakes and wetlands in the delineated drainage basin.
Length of Main Channel (LNTH): The length of the longest calculated drainage line within the derived watershed.
Slope of Main Channel (SLP): The slope of the longest channel within the delineated watershed.
Mean Elevation (ME): The average elevation value of the digital elevation model within the delineated drainage basin.
Base Flow Index (BFI): The ratio of base flow to total flow volume.
River Type: Flow type can be classified as perennial or intermittent and warmwater or coldwater.
Bankfull Width: Approximately equal to the wetted width at the highest annual flow stage. Typically measured at a riffle (cross-over point).
Mean Wetted Width: The average at each site of the total bank to bank width of stream as measured perpendicular to current flow at the water's surface.
Mean Max Depth: The average at each site of the max depth of the stream measured with a ruler or tape at the thalweg.
Mean Hydraulic Head: The average at each site of the height of water "piled up" (above the water's surface) against the wide side of a meter stick held vertically in stream (always measured at the thalweg).

Percentage cover of different land coverge types in each of the drainage basins

Land Type (%)	Spring Creek (Site 1)	Spring Creek (Site 2)	Crane River	Willow Creek
Water	11.70	0.00	5.28	0.78
Freshwater Coastal Marsh / Inland Marsh	7.18	2.16	3.40	3.32
Deciduous Swamp	1.04	0.00	1.17	1.83
Conifer Swamp	3.19	1.61	0.98	6.60
Open Fen	1.15	0.00	0.49	2.15
Dense Deciduous Forest	6.93	5.05	10.91	0.00
Dense Coniferous Forest	28.78	57.27	29.36	77.37
Mixed Forest Mainly Deciduous	21.53	5.82	18.26	0.98
Mixed Forest Mainly Coniferous	13.30	28.08	12.79	6.21
Sparse Deciduous Forest	1.89	0.00	3.52	0.00
Pasture and Abandoned Fields	1.72	0.00	12.66	0.09
Cropland	1.58	0.00	1.17	0.67